A QUANTITATIVE AND QUALITATIVE STUDY OF THE INDIGENOUS FORESTS OF THE SOUTHWESTERN CAPE

BY

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PHOTO 7: A wet forest stand along a stream. Trees in the foreground are mainly *Rapanea melanophloeos* and *Cunonia capensis*.

PHOTO 8: A moist forest stand on the edge of the road through Grootvadersbos forest. Important species include *Olinia ventosa*, *Rothmannia capensis* and *Burchellia bubalina*.

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INTRODUCTION

The vegetation of the south-western corner of South Africa is dominated by low sclerophyllous shrubland and is largely lacking in trees (Taylor, 1978). Forest is more-or-less restricted to sheltered valleys, southern slopes and rock screes (Campbell and Moll, 1977; Taylor, 1978). Early botanists referred to the forests as containing 'tropical' species in contrast to the temperate Cape flora (Acocks, 1953; Phillips, 1931). However, White (1978) showed that these forests were overwhelmingly afromontane in species composition; an effect of increasing latitude compensating for altitude in this region.

These remnant forest patches have been little studied in the past, work of Phillips (1931), Laughton (1937) and von Breitenbach (1972) being the best known for the Knysna region, while Muir (1929) described the forests around Riversdale, Taylor (1955) those of Grootvadersbos near Heidelberg and Adamson (1927) and Campbell and Moll (1977) those of Table Mountain. These remnant forests are of particular interest considering their position in the Cape Floral Kingdom (which is one of the six floral kingdoms of the World (Good, 1964)), their rarity, conservation future and floristic composition.

The forests were heavily exploited after the arrival of the Europeans in 1652 (Hartwig, 1973) and have been adversely affected by fires and the encroachment of alien species.

This study was undertaken to investigate the floristic relationships between the forest remnants in the south-western Cape with special reference to the tree component. A classification (Werger, 1974) and ordination (Bray and Curtis, 1957) technique have been employed to establish the floristic relationships existing between the forests.

The above two techniques have in the past been considered as alternatives (see Mueller-Dombois and Ellenberg, 1974) but can, in fact, be complementary (Mueller-Dombois and Ellenberg, 1974). The object of using both methods in this study was to see if the ordination technique could elucidate any further information over and above that provided by the classification method.

CHAPTER I

PHYSIOGRAPHY

1.1 LOCALITY

The study region is situated in the south-western corner of the Cape Province, South Africa (see inset Fig. 3), bounded by Cape Agulhas (34° 50'S, 20° 00'E) to the south and 33° 35'S to the north. The Cape Peninsula (18° 25'E) and the Jonkersberg forest complex (22° 20'E) form the western and eastern boundaries respectively.

The forests surveyed occur mainly on the southern slopes of the major mountain ranges (see Fig. 1 and Fig. 6).

1.2 TOPOGRAPHY AND GEOLOGY

The landscape is dominated by the ranges of the Cape Fold belt which in the study area runs almost parallel to the coastline. In the east these ranges strike from east to west, while in the west the strike is nearly north-south (see Fig. 1). The forelands on the coastal side of these ranges consist of low peneplained erosion surfaces and flat plains (Wellington, 1955). The broad valley bordering the mountains to the interior - known as the Little Karoo - is broken in places by anticlines which form a number of mountainous complexes.

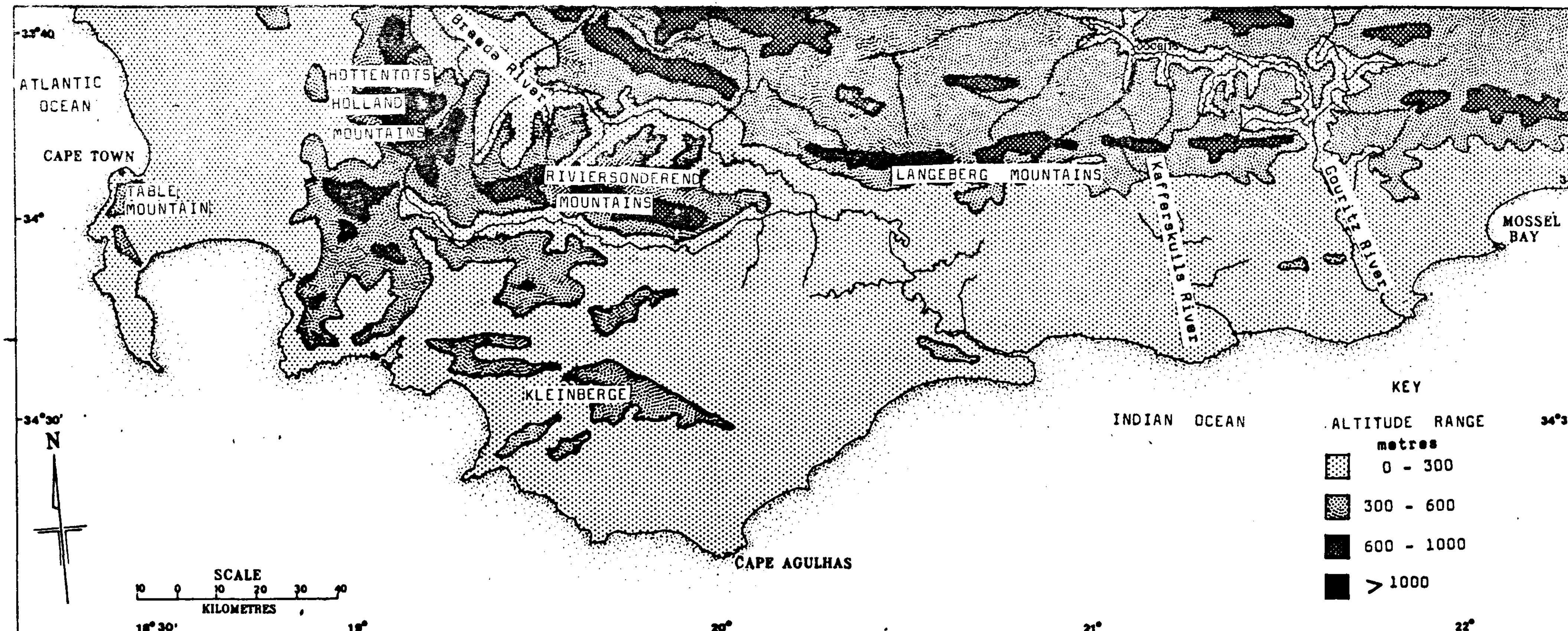


FIG.1 Topography of the study area(after Trigonometrical Survey Office,1962)

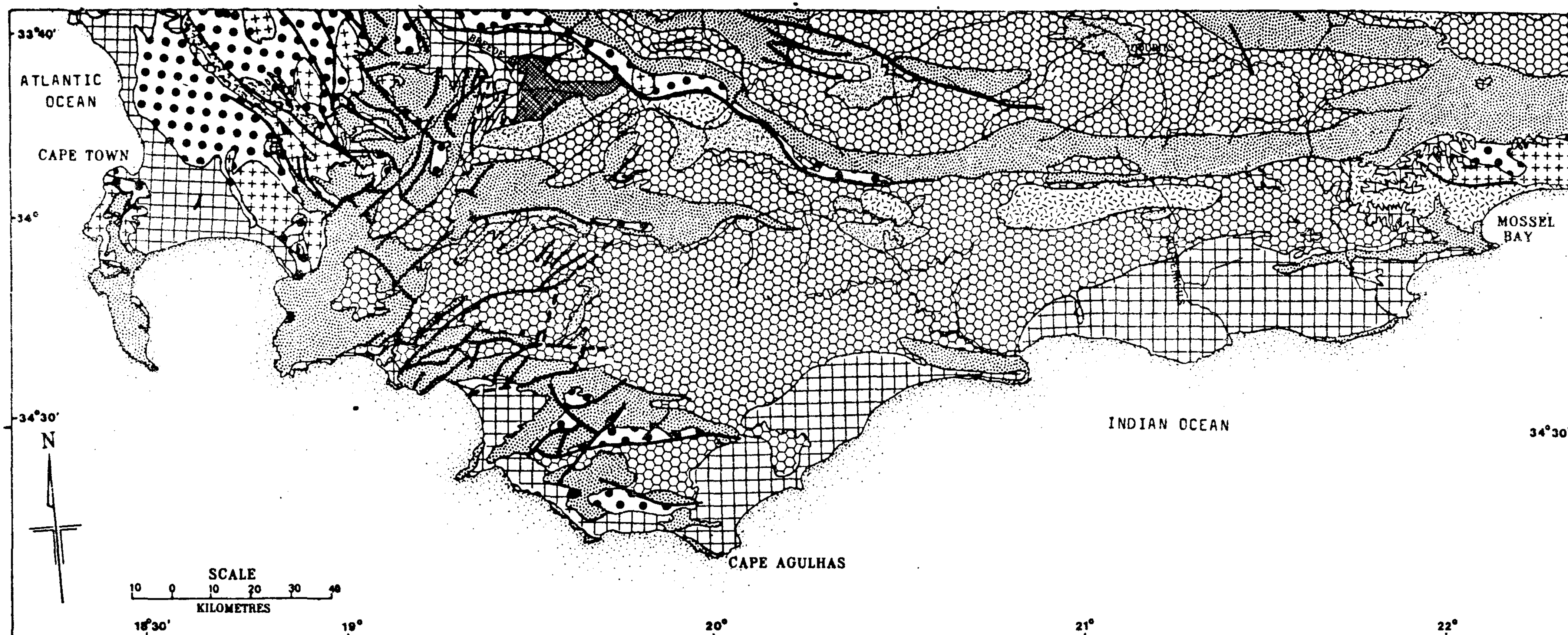


FIG.2 Geology of the study area(after Geological Survey,1970)

<u>KEY</u>

- Unconsolidated superficial deposits
- Quartzite and shale(Table Mountain Series)
- Shale,sandstone(Bokkeveld Series)
- Cape granite
- Shale(Malmesbury beds)
- Conglomerate,sandstone,shale, limestone(Lower Series)
- Quartzite(Witteberg Series)
- Sandstone,shale(Dwyka Series)
- Faults

There are three main geological formations present : the Late Precambrian Nama system, the Ordovician to Devonian Cape Supergroup, and Tertiary and Quarternary deposits. The strata of the Cape Supergroup rest on Precambrian shales and siltstones of the Malmesbury Formation which are exposed on the coastal forelands of the western sector of the study area. The Cape Supergroup comprises strata of the Table Mountain Group, the Bokkeveld Series and the Witteberg Series. The mountains are capped by rocks of the Table Mountain Group; being largely Table Mountain and Witteberg quartzites (Fig. 2) which are up to 3700m thick and these represent anti-clines of Permo-Triassic age (Rust, 1967).

The major mountain ranges are the Hottentots Holland, Riviersonderend and Langeberg mountains. These mountains rise sharply from the coastal forelands to over 1500m above sea level (a.s.l.), with Lemoenshoek Peak (20° 52'E, 33° 55'S) in the Langeberg being 1650m a.s.l. and Sonder-eind Peak (19° 52'E, 34° 4'S) in the Riviersonderend mountains being 1670m a.s.l. The Hottentots Holland range is over 2000m a.s.l. in a number of places. The other mountainous regions in the study area are the Cape Peninsula Mountain Chain, with Table Mountain itself reaching an altitude of 1090m a.s.l., and the Klein River range which reaches some 630m a.s.l. (see Fig. 1 and Fig. 2). The broad valley to the north of the Riviersonderend and Langeberg ranges consists of shale of the Bokkeveld Series.

This valley is broken in places by mountainous complexes which are composed largely of quartzites of the Table Mountain Group.

Early Cambrian intrusions of Cape Granite commonly form the foothills and slopes of the mountains, especially in the west.

South of the Langeberg and Riviersonderend ranges an undulating lowland usually less than 300m a.s.l., is the dominant feature of the landscape. The dominant geological formation covering the area are the shales of the Bokkeveld Series. Nearer the coast this coastal foreland is buried by aeolian sands of recent origin forming a narrow plain up to 20km wide in places. Outcrops of coastal limestone of Tertiary to Recent Origin (Tankard, 1976) form low hills in this region but mountain relicts of Sandstone and Cape Granite are also present. The coastal forelands in the north-west are comprised of exposed Malmesbury shales of the Archaean complex (see Fig. 2). Over most of this area the topography is characterised by broad, gently undulating landscapes with outcrops of granite massifs rising to some 800m a.s.l. (Tankard, 1976), and quartzitic ranges, outliers of the mountain system to the east, rising to 900m a.s.l. A narrow coastal plain sometimes 30km wide is found closer to the sea and here aeolian sands have covered the shales. The plain is extremely flat and seldom reaches heights of over 150m a.s.l.

A wide plain of aeolian sand also exists between the Hottentots Holland range and the Cape Peninsula Mountain Chain. Closer to the sea in the regions covered by recent sands naked dunes may be found, but most are vegetated.

Two main rivers pass through breaks in the mountain ranges of the eastern sector, these being the Breede River and the Gouritz River (see Fig. 1). The Breede River rises in the mountains to the north of the Hottentots Holland complex and passes through the gap between the Langeberg and Riviersonderend ranges. The Gourtiz River rises in the mountains of the interior, to the north of the study region, and in contrast to the Breede River which is a mature river, it is in a youthful phase and is characterised by steep gorges, following a more direct route to the coast. A number of smaller rivers drain off from the Langeberg and Riviersonderend ranges, for example the Kafferkuils River, but these do not carry much water. In the western sector the rivers are much smaller and usually only flow during the winter months.

The topography and geology of the region have a big influence on climate and vegetation, the vegetation boundaries following closely the major geological formations (see Fig. 2 and Fig. 6).

1.3 SOILS

There is no adequate, detailed map of the soils in the study region and this summary has, therefore, been compiled from a number of sources (Talbot, 1947; Taylor, 1969; Neethling, 1970; Boucher, 1972; Ellis, 1973; Kruger, 1974; Smith-Baillie, Rudman, Oosthuizen, Ellis and Dohse, 1976; and Kruger, 1978).

The soil types are essentially correlated with the underlying parent rock. Most are structureless, acid to very acid (pH usually less than 5), and many are podzolised to some degree. These soils, with unusually low levels of phosphorous and nitrogen (phosphorous 3 - 40 p.p.m. and nitrogen 0,1 - 0,4 per cent), have developed from very old parent materials (typically quartz and sandstone) which are heavily weathered.

Quartzite parent material gives rise to loamy-sands or sands, while granite and shale give rise to either sandy-loams, sandy-clay-loams or clay-loams. Most of the profiles drain freely, but some may be seasonally or perennially wet or waterlogged if drainage is obstructed. However, with the finer textured soils, on which a large portion of the indigenous forests occur, much water is lost as run-off as there is a resistance to water infiltration due to the small pore-size of the soils. Worral (1960) suggests that the reason for forests extending further into more arid regions on coarse-textured soils is because water infiltration in the coarser soils is higher.

The soils weathered from quartzites are essentially pale grey, shallow (less than 300mm) and sandy. The general topography of the areas where quartzite is found varies from very steep cliffs, through gently sloping ground, to areas that are relatively level. Large boulders and rocky outcrops occur extensively on the steeper areas and here there is little or no soil mantle. Table Mountain Sandstone colluvial drift has often accumulated on more gentle slopes and in areas that are more or less level. Waterlogging can occur on these gently sloping sites during the wetter months especially where the underlying, impermeable bedrock, forms depressions. In areas where colluvial drift has occurred, the soils are somewhat deeper and in various stages of development. It is on these areas of sandstone colluvial drift where the majority of forests which occur on soil derived from the quartzitic parent material are found.

Forests also occur in regions of contact between the Table Mountain Series and the younger Bokkeveld Shales. Here the soils exhibit intermediate features, the top layers are often of deep (greater than 0,5m) Table Mountain sandstone derived, colluvial sand overlying reddish or yellowish clay, which is shale derived. The soils formed from shales are generally deeper (1m or greater) and contain a larger percentage of clay (greater than 35%) than the soils derived from quartzite (usually less than 10%). These soils of the lowlands are often loamy to silty-loamy in the upper soil mantle (±150mm), and clayey below this. These soils differ greatly from the sands in texture; the smaller particle size causing impeded drainage which results in gleying and plinthification. In contrast to the soils derived from quartzitic rock, the soils of the shales are richer in plant nutrients and are able to produce significant growth of agricultural plants; wheat being the main crop planted on the undulating hills of the lowlands in the east and west.

Soils that are formed from granite parent material, are usually moderately to well drained, except adjacent to low-lying watercourses where waterlogging is a problem. Most of these soils are deep (greater than 1m) and relatively free of rock outcrops because granite weathers deeply. Soils formed from pure granite have a high clay content (25 - 30%), but where the granite has been mixed through colluvial action with weathered Table Mountain Sandstone, coarser soils with less clay (10 - 15%) occur. Where wind blown materials have mixed with weathered granite, very sandy soils (less than 6% clay) are found.

The soils of the coastal region are recent sands of varying depths and usually very acid (pH ±4). During the rainy season these soils can become waterlogged, with watertables rising to within 200mm of the surface and occasionally above ground level. Soils of the limestone hills in these regions are usually less than 0,5m deep and are dark grey to black and usually slightly alkaline.

Soil forms as classified by the Soil Classification Working Group (1976) are recognised on the basis of topsoils, sub-soil horizons, and are subdivided into series. Many soil forms occur in the study area, the main ones are tabulated below.

TABLE 1

DOMINANT SOIL FORMS IN THE VARIOUS ZONES OF THE STUDY AREA (DATA FROM KRUGER, 1978)

AREA	SOIL DEPTH	SOIL FORM
Coastal	deep (>0,5m)	Fernwood
	shallow(<0,5m)	Mispah
Mountain and foothills	shallow(<0,5m)	Mispah
		Glenrosa
		Cartref
	deep (> 1m)	Hutton
		Clovelly

CHAPTER II

CLIMATE

2.1 INTRODUCTION

Three climate zones occur in the study area (Schulze, 1965); namely the mediterranean climatic zone ("M"), the Karoo climatic zone ("K") and the Southern Cape Coastal climatic zone ("A"). This division into regions is based primarily on geographic considerations, the prominent mountain ranges forming the main dividing lines with other features such as rivers and proximity to the coast being considered of secondary importance. Fig. 3 shows the distribution of the climate zones with superimposed isohyets. The important place names, which are referred to in Tables 2, 3, 4 and 5, are also included on Fig. 3. Precipitation and temperature are discussed separately for the three climate zones, whereas the other climate parameters such as winds and mists are discussed in general for the whole study area as data for these parameters are limited. Summaries of selected rainfall and temperature data for various stations in the three climate zones are tabulated in Tables 2, 3, 4 and 5.

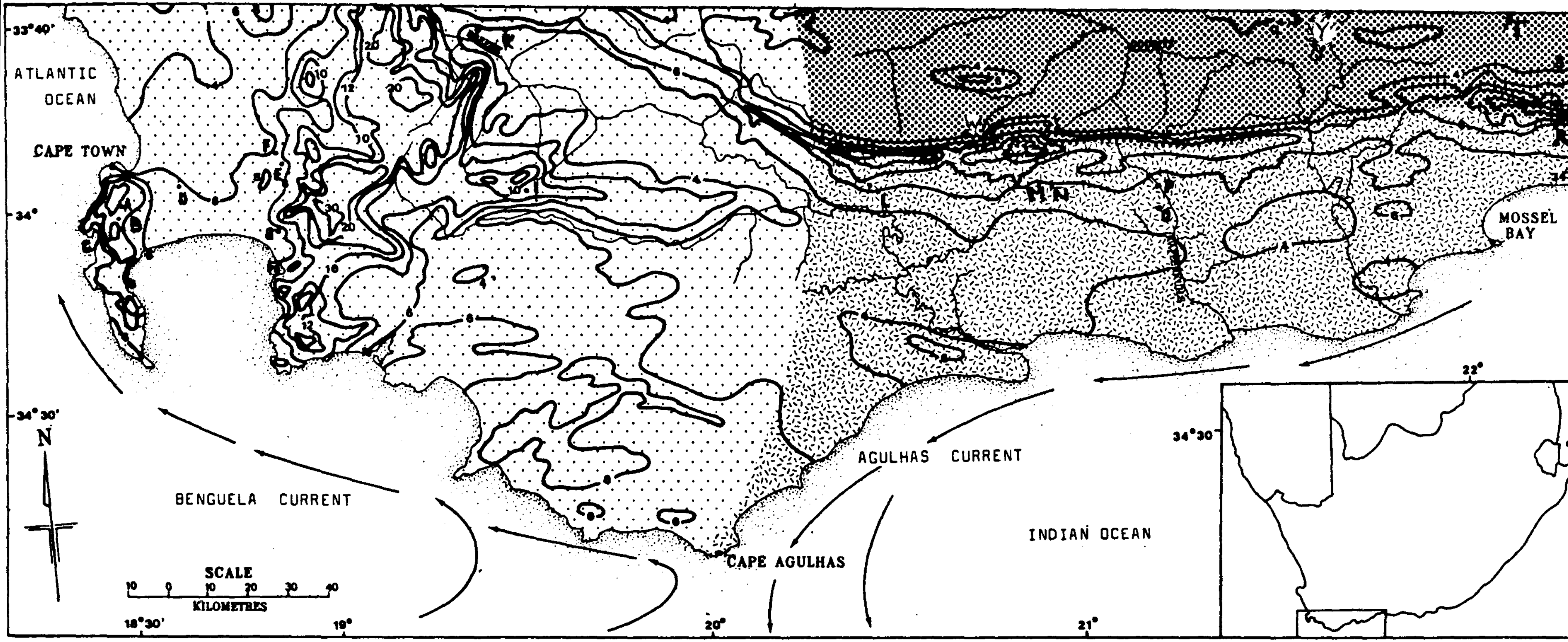


FIG. 3 Distribution of the Climate zones(Schulze,1965), isohyets(Trigonometrical Survey Office,1966) and stations referred to in the text. Inset shows study region in relation to Southern Africa.

KEY

ZONES

- Mediterranean
- Southern Cape
- Little Karoo

Isohyets(x 100mm)

STATIONS

A Kirstenbosch	H Steenbras	P Garcia	
B Groot Constantia	I Genadendal	R Jonkersberg	
C Silvermine	K Worcester	S Kammanassie Dam	
D D.F.Malan	L Swellendam	T Oudtshoorn	
E Jonkershoek	M Srawberry hill	Y Calitzdorp	
F Elsenberg	N Heidelberg	W Barrydale	
G Lourensford	O Riversdale		

2.2 PRECIPITATION

2.2.1 Mediterranean zone ("M")

The area with a mediterranean climate is found in the south-western corner of the study area, within a radius of some 200km from Cape Town. This area receives more than 75% of its annual rainfall during winter, from about April to September, and has a warm to hot summer (see Section 2.3.1 and Tables 2 and 3). The rainfall is profoundly influenced by the very pronounced orographic features which result in 3000mm of rainfall being recorded in some mountain kloofs, as against 400-500mm on the Cape Flats between the Hottentots Holland and the Cape Peninsula. Less than 250mm of rainfall is recorded annually from the Breede River valley, this being a typical "rain shadow" effect.

The rainfall is mainly cyclonic and orographic, but very occasionally thunderstorms do occur (Schulze, 1965). In addition precipitation on the mountains is enhanced in summer by the frequent mists that occur in this region (Marloth, 1904; 1907; Nagel, 1956; 1961 and 1962). This phenomena, which is of particular importance to the forests, is discussed in detail in Section 2.4.

Table 2: Average annual rainfall (mm), number of days with summer and winter rain and percentage of summer and winter rainfall for selected stations in the study area (summer is taken from October to March and winter from April to September) (Weather Bureau, 1964).

Station	Climatic Zone	Co-ordinates		Height (m)	Rainfall (mm)				
		S	E		Mean Annual	% Summer	% Winter	No. of days with Summer rain	No. of days with Winter rain
Jonkershoek	M	33°58'	18°26'	274	1108	23,6	76,4	38	75
Kirstenbosch	M	33°59'	18°26'	89	1413,9	19,5	80,5	39	89
Silvermine	M	34°04'	18°24'	442	1294,4	25,4	74,6	37	68
Worcester	M	33°39'	19°26'	228	315,8	34,2	65,8	8	24
Heidelberg	A	34°05'	20°58'	84	407,7	48,4	51,6	30	36
Riversdale	A	34°06'	21°16'	111	461,5	49,3	50,7	36	43
Mossel Bay	A	34°10'	22°08'	76	530,3	45,6	54,4	24	27
Swellendam	A	34°01'	20°26'	122	830,7	56,1	43,9	46	44
Jonkersberg	A	33°55'	22°14'	457	1075,4	59,5	40,5	57	47
Barrydale	K	33°54'	20°44'	290	273,6	44,4	55,6	34	17
Calitzdorp	K	33°32'	21°41'	238	199,2	57,0	43,0	83	17

Table 3: Average monthly and annual rainfall (mm) for selected stations in the study area (Weather Bureau,1964)

Station	Annual	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Kirstenbosch	1414,9	33,6	26,7	35,8	109,6	200,5	237,7	238,2	211,7	139,3	91,2	56,6	33,0
Jonkershoek	1068,0	28,0	28,0	32,0	91,0	149,0	157,0	162,0	137,0	118,0	76,0	54,0	34,0
Steenbras No.1	874,0	26,9	30,3	31,5	83,2	126,5	135,5	118,9	110,5	80,0	62,3	40,3	27,7
Genadendaal	653,6	37,1	37,3	56,6	56,1	54,4	61,2	64,3	65,0	69,6	60,5	58,7	32,8
Lourensford	920,4	28,7	21,1	25,7	71,4	122,2	153,2	148,6	125,2	95,8	59,2	47,2	22,1
Swellendam	830,7	68,1	74,5	88,1	62,5	57,6	42,1	52,6	69,4	80,2	91,5	86,9	56,9
Riversdale	447,0	23,0	34,0	51,0	37,0	35,0	31,0	38,0	33,0	42,0	45,0	49,0	27,0
Strawberry Hill	1066,2	87,0	102,8	118,2	88,9	73,7	58,1	68,7	77,2	94,1	104,6	103,6	89,3
Garcia	610,6	53,8	53,2	79,5	51,8	44,1	28,3	40,6	42,1	60,9	63,1	57,2	34,0
Jonkersberg	1075,4	101,3	98,6	127,4	76,9	68,5	46,9	62,7	79,9	99,9	99,3	114,6	99,4
Calitzdorp	199,2	15,5	20,6	25,8	20,2	14,7	10,9	10,0	11,9	17,7	17,2	18,0	16,7
Oudtshoorn	240,1	13,4	17,2	26,4	20,3	21,5	13,3	20,1	18,9	20,5	21,1	28,4	19,0
Kamanassie Dam	232,2	9,7	13,0	28,7	25,7	22,3	17,8	19,1	14,7	22,1	18,0	24,4	14,7

2.2.2 Southern Cape Coastal zone ("A")

The Southern Cape Coastal zone which receives rainfall equally in all seasons is found in the south-eastern region of the study area, from Swellendam eastwards (see Fig. 3, and Tables 2 and 3). As in region "M", the rainfall varies considerably depending on topography. On the mountain ranges annual amounts may exceed 1000mm, whereas the plains to the south receive barely 400mm annually. Up to 100 rainy days per annum can be expected with anything from 8 to 12 rain days per month (see Table 2). Rainfall is mainly cyclonic and orographic, thunderstorms occuring on about ten occasions per year almost exclusively in summer (Schulze, 1965). The effective precipitation on the Langeberg range is also enhanced by the mists which occur frequently in summer (see Photo 1).

2.2.3 The Little Karoo zone ("K")

This inland region lies north of the Langeberg and usually receives less than 250mm of rainfall per annum. As in region "A" this is fairly evenly distributed throughout the year (see Tables 2 and 3), with one to three rainy days per month (Schulze, 1965). Ten to twenty thunderstorms occur in this region per year, and one occasional heavy storm can account for as much as half the normal annual rainfall (Schulze, 1965). For example the rainfall statistics for Calitzdorp (Table 2) show that only 17 rainy days out of a total of 100 (i.e. 17%) occur in winter, yet the percentage of winter rainfall is 43%, indicating that substantially more rain falls on winter days than on summer days. In contrast to zones "M" and "A", the annual precipitation is not enhanced by mist from orographic cloud.

2.3 TEMPERATURE

2.3.1 Mediterranean zone ("M")

The average daily maximum temperature is about 28°C in mid-summer (December-January) and 17°C in mid-winter (June-July), but extreme maxima can reach 43°C and 30°C respectively (Schulze, 1965). In January the average daily minimum temperature is around 15°C while in July it is around 6°C though extreme minima, largely depending on altitude, can fall to 4°C and -5°C respectively (Schulze, 1965). Table 4 indicates the daily summer and winter maximum and minimum temperatures for four stations in the mediterranean zone. Summer is taken as stretching from October through to March, and winter from April through to September. Average monthly maxima and minima are tabulated for two stations in this zone, these being Kirstenbosch (33° 59'S, 18° 26'E) and Steenbras No. 1 (34° 11'S, 18° 51'E) (see Table 5).

Table 4: Daily summer and winter maximum and minimum temperatures for selected stations in the study area(Weather Bureau,1954).

Place	Co-ordinates		Height	Temperature 0° C			
	South	East	Metres	Mean daily Summer max	Mean daily Winter max	Mean daily Summer min	Mean daily Winter min
<u>Zone M</u>:							
Elsenberg	33°51'	18°50'	180	26,26	19,32	13,6	9,22
Kirstenbosch	33°59'	18°26'		22,9	18,5	13,6	9,96
Groot Constantia	34°02'	18°25'	61	23,23	18,48	13,8	10,1
Worcester	33°39'	19°26'	228	27,2	20,4	13,98	7,98
<u>Zone A</u>:							
Heidelberg	34°05'	20°58'	84	27,25	22,1	12,83	5,98
<u>Zone K</u>:							
Jobertsdal	33°58'	20°18'	180	27,5	20,4	11,75	6,6
Kamanassie Dam	33°39'	22°25'	308	29,03	22,01	13,55	6,38

Table 5: Average monthly maximum and minimum temperatures (0^oC) for selected stations in the study area (Weather Bureau, 1954).

Station	Kirstenbosch		Steenbras		Heidelberg		Worcester		Kamanassie Dam	
Month	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
January	32,3	11,6	32,8	9,7	36,9	10,2	38,0	10,4	41,3	11,1
February	34,5	11,5	32,2	11,2	37,8	10,3	37,8	11,4	40,3	10,7
March	33,1	10,6	30,4	8,9	35,9	7,6	35,8	9,4	37,8	9,1
April	33,4	8,8	30,1	7,3	34,8	5,0	33,4	6,6	35,8	5,9
May	28,2	6,9	26,3	4,7	30,2	2,1	28,6	3,5	29,3	2,9
June	24,6	5,8	24,1	3,0	26,9	-0,2	25,6	1,6	26,8	0,5
July	24,8	5,2	22,7	2,4	27,5	-0,7	24,4	1,1	26,1	0,0
August	26,1	4,5	25,4	2,9	30,1	0,2	28,0	1,8	30,1	0,6
September	26,7	5,4	26,6	4,6	32,4	1,3	30,4	3,1	33,4	2,4
October	28,8	6,8	28,1	5,2	33,6	3,8	34,4	4,4	35,3	3,7
November	29,9	8,0	30,7	6,9	35,1	5,9	35,4	7,5	36,9	7,2
December	31,7	9,7	31,4	8,2	35,9	7,9	37,0	9,6	40,2	9,5

2.3.2 Southern Cape Coastal zone ("A")

Temperatures in this region can occasionally rise above 38°C during hot "berg winds", whose average occurrence is one to three per month during the summer (Schulze, 1965). The average daily maximum temperature is about 26°C in January and 19°C in July; extremes may reach 42°C and 32°C respectively. The average daily minimum temperature is about 15°C in January and 7°C in July, while extremes can occasionally drop to 4°C and -4°C respectively.

Mean daily summer and winter maximum and minimum temperatures for Heidelberg (34° 05'S, 20° 58'E) in the centre of the zone are given in Table 4, and the monthly maximum and minimum temperatures are presented in Table 5.

The average daily maximum and minimum temperatures for summer are very similar to those of the mediterranean zone, as are the respective extremes. However, average daily winter maximum temperatures are slightly less (± 1°C) than the mediterranean zone, while daily winter minimum temperatures are usually between 4°C and 5°C less than the mediterranean zone.

2.3.3 Little Karoo zone ("K")

This region is characterised by very large temperature fluctuations, both diurnally and seasonally. Days can be excessively hot and temperatures up to 44°C due to hot winds off the high plateau are not uncommon. Nights can be chilly with a range of 28°C between day and night not being unusual. The average daily maximum temperature is about 32°C in January and 18°C in July, while extremes of 45°C and 31°C respectively have been recorded.

Average daily minima are about 15°C in January and 5°C in July, and extreme minima can drop to 5°C and -3°C respectively. Daily summer and winter maximum and minimum temperatures for Joubertsdal and the Kammanasie Dam are given in Table 4, while Table 5 gives the average monthly maximum and minimum temperatures for the Kammanasie Dam and Worcester. Although Worcester (33° 39'S, 19° 26'E) is essentially in the mediterranean zone, the temperatures are representative of much of the area of the Little Karoo. This is because Worcester is inland in a valley, therefore, temperatures are more like Heidelberg.

2.4 MISTS

Mist is considered to be an important contributor to the total precipitation received in the study area (Marloth, 1904; Nagel, 1956). The upper mountain slopes are frequently covered by orographic cloud which is induced by the anti-cyclonic south-easter, especially during the summer months. Marloth (1904) was one of the first people in South Africa to comment on the considerable amount of water which was deposited, especially on vegetation, when Table Mountain was covered with cloud. At times it has been noted that precipitation from mist is sufficient to increase flow rates in mountain streams (E.A.C.L.E. Schelpe pers-comm, 1977).

Marloth (1904) measured considerable increases in the amount of precipitation in condition of mist and rain, as compared to rain alone. Nagel (1956) took readings for the same area and obtained results for precipitation on Table Mountain in 1956 as 3294mm due to mist, as opposed to 1940mm in the same year due to rainfall alone. The mean intensity of rainfall was measured at 1,84mm per hour, and for mist precipitation at 3,74mm per hour. Nagel (1962) derived an empirical equation to calculate the amount of mist precipitation and used it to indicate that, in the extreme case of Table Mountain (1087m a.s.l.), mist precipitation amounted to 5700mm yr^{-1} as opposed to rainfall of about 1900mm yr^{-1}. The ratio of rain to mist was 2:4 in winter, and 4:7 in summer. In summer a significant proportion of mist occured without rain. Kerfoot (1968) mentioned that mist precipitation had not been satisfactorily measured although there is little doubt that orographic mist is important ecologically. What is required now is a quantitative value of its importance. Kruger (1974) showed by means of a Grunow mist guage that precipitation without rain in the Hottentots Holland Mountains occured on between 20 and 36 dyas per year, and most of this was in summer.

Summer orographic cloud also occurs on the mountains of the Langeberg (Marloth, 1907) and one can stand beneath the forest canopy and get wet from water dropping off the leaves during mists in the absence of rain. It is evident that this mist precipitation plays an important role in moderating summer drought at upper elevations, and it may be a highly significant input in the hydrological cycle. This mist precipitation is thought to be an extremely important climatic factor in the ecology of the indigenous forests, especially where the forests are not restricted to kloofs and streams and therefore able to tap the additional water they require.

The effects of the warm, Mocambique ocean current, which reaches as far south as Cape Agulhas, are felt on the slopes of the Langeberg and Riviersonderend Mountain ranges. It is on these two mountain ranges where the majority of the larger forest patches occur. The temperatures and moisture content of the air moving over this current obviously has an effect on the inland mountains, especially in summer when the southeasterly winds often carry low cloud inland.

Mist and rainfall precipitation are important factors controlling forest distribution in Southern Africa, mist occuring quite frequently on mountain ranges above 305m, for example the Karkloof Range in Natal. Phillips (1926) stated that mist was an important contributor to total precipitation, particularly where some physical barrier prevented advancement, and it was in this region that forest often occured. The Karkloof forest on the Karkloof Range in Natal is a typical example (Moll, 1971). This forest, situated on southerly aspect slopes facing the sea, receives a lot of mist and is partly sheltered from the dessicating northwesterly Berg winds. Edwards (1967) and Killick (1958 and 1962) refer to the same phenomena in other forests of Natal. The same criteria apply to the forests of the study area, particularly those forests on the Langeberg and Riviersonderend Mountain Ranges.

Further south of Cape Agulhas the influence of the ocean current on the vegetation is slightly different. Here, the cold Benguela current and the cooler air above it, which then blows into the interior, results in the vegetation being somewhat drier and the forests are, therefore, less extensive (Rumney, 1968). Mists, however, are as an important source of precipitation to the forests in the south-west, especially in summer, as it is to those forests further east.

2.5 WINDS

The weather of the study region, like the rest of Southern Africa, is dominated by the general circulation of the subtropical anti-cyclones. "The winter circulation of the South-western Cape is associated with circumpolar westerly winds, taking the form of a succession of eastward moving cyclones and anti-cyclones. Originating far to the south of Southern Africa, these disturbances first bring rain to the south and south-eastern coasts and the rain may even extend far inland. Fronts are associated with the cyclones, warm fronts being diffuse and cold fronts being more usual. Most winter rainfall occurs in association with north-westerly pre-frontal winds, but storms occur after the passage of a cold front when the winds back from north-west to west and south-west, the pressure starts rising and temperatures fall" (Jackson and Tyson, 1971). Föhn like "bergwinds" often precede winter anti-cyclones when dry subsiding air moves off the interior plateaux in response to strong coastward pressure gradients (Tyson, 1964).

Summer weather arises primarily as a result of the slight southward displacement of the subtropical high pressure belt over the oceans. This belt is in the form of anti-cyclones which travel eastward and along the coast blocking the westerly cyclones. As a result the study area experiences weather characterised by warm, dry conditions with frequent strong south-east winds (Wellington,

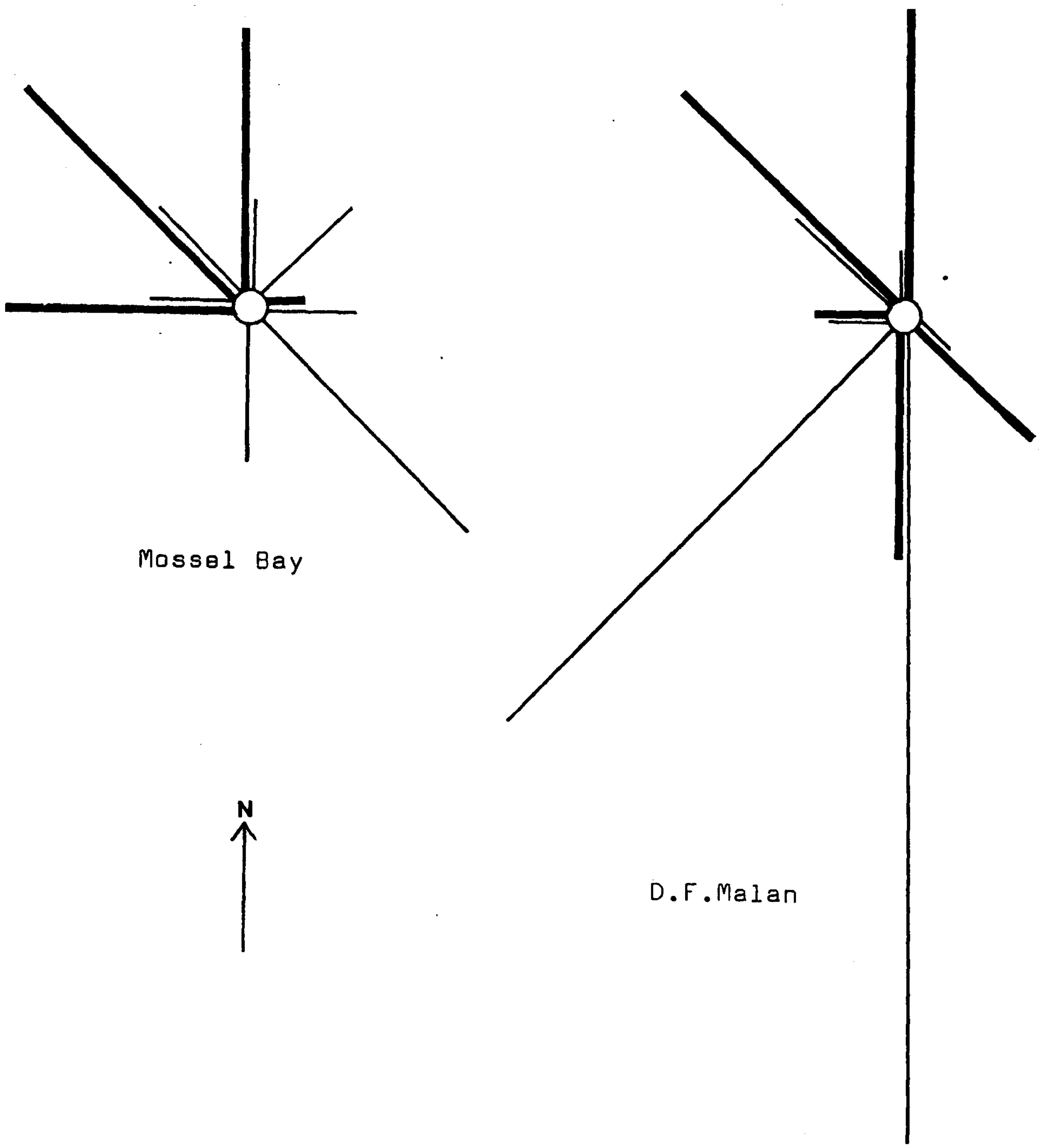


FIG.4 Wind roses for two stations in the study area.Length of lines indicate relative duration of wind from particular direction(data from Weather Bureau,1975).

——— January
━━━ July

1955; Schulze, 1965).

The mediterranean zone and the Southern Cape Coastal zone thus experience winds mainly from the southeast in summer, while the Little Karoo zone, in addition to winds from the south-east, experiences hot winds which blow off the escarpment from the north. In winter the winds in all three zones are mainly northwesterlies with bergwinds blowing off the escarpment to the north under the conditions described above. Wind Roses are presented in Fig. 4 to show the variations in strength and direction of the wind for two areas in the study zone.

2.6 SYNOPSIS OF CLIMATIC CONDITIONS

The four climatic parameters discussed above are the most significant factors determining the distribution and ecology of the vegetation and are briefly summarised below. Winds are predominantly southeast in summer, producing orographic cloud responsible for the mists which are an important additional contributor to precipitation. The winter winds are largely north-westerlies bringing the majority of the rain to the Mediterranean zone and some to the Karoo and South Coast zone. Rainfall is high (greater than 700mm) on the mountain ranges, but is often less than 400mm on the coastal forelands and Karoo interior. Both seasonal and daily temperature fluctuations are high in the interior but only moderate in the Mediterranean and

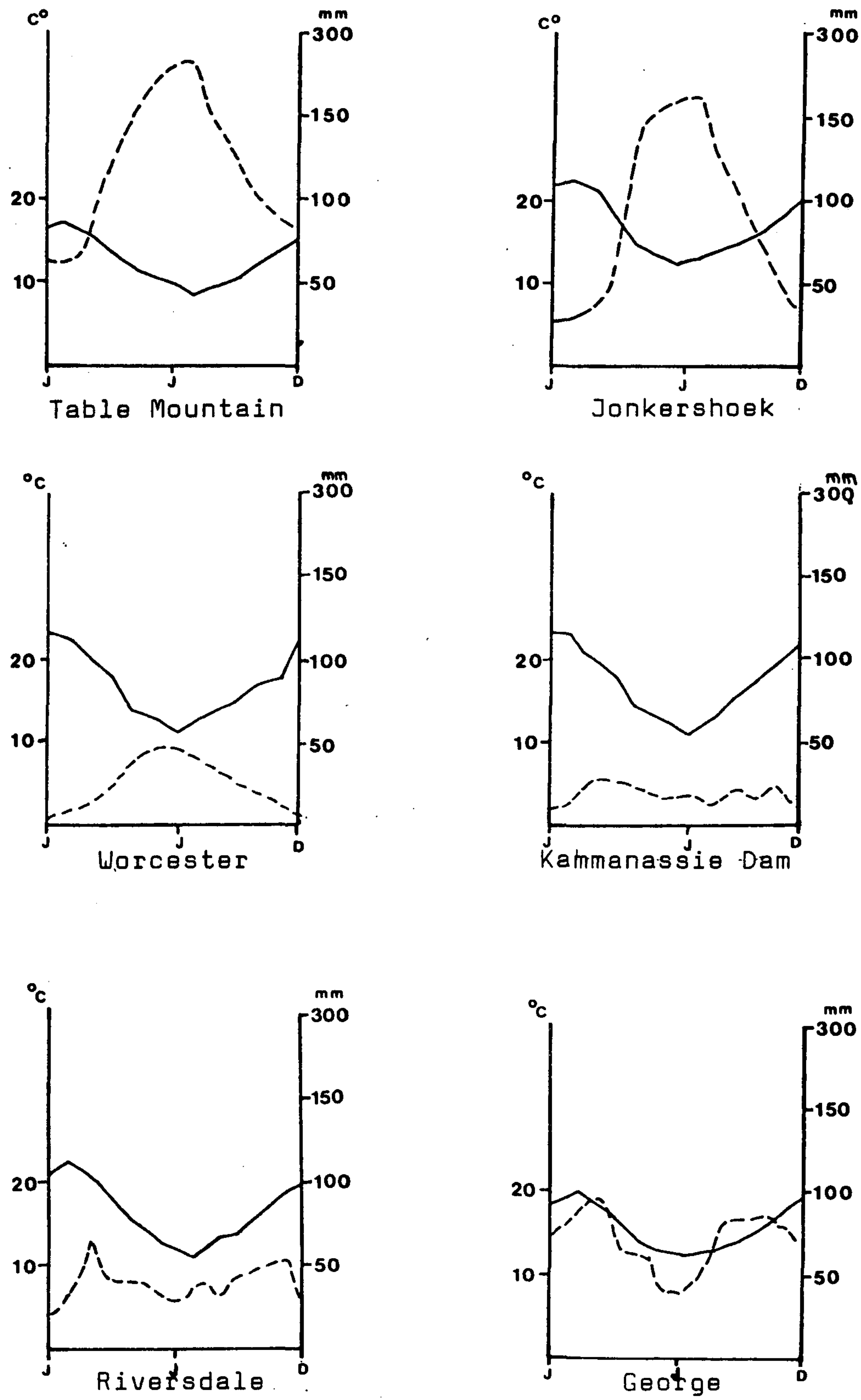


FIG. 5 Walter-Leith climatographs(Walter and Leith,1960) for various stations in the study area.

----- Rainfall

——— Temperature

Southern Coastal zone. Walter-Leith diagrams are presented in Fig. 5 for a number of weather stations in the three zones.

Frost is virtually unknown in the Mediterranean zone, occuring only occasionally on high mountains, but the plains of the Southern Coast zone and the Karoo region have frost in the winter months. Snow only occurs on the higher mountains above 1000m, but only persists in areas greater than 1500m (Kruger, 1978) in the Mediterranean zone and Southern Coast zone. In the Little Karoo zone it is not unusual to have snow in the lowlands, but it does not persist.

CHAPTER III

VEGETATION CHARACTERISTICS OF THE STUDY REGION

The vegetation of the study area and the area, surrounding it, is both complex and varied. Nine of Acock's Veld Types (Acocks, 1953) which occur in the vicinity of the study area are briefly described. Although most of them have no great relationship to the forest flora, it is deemed necessary to describe the surrounding vegetation to indicate the variety in height, cover, life form and range of the various types. Most of the Veld Types are related to Veld Type 69 (Macchia) or to Veld Type 26 (Karroid Broken Veld). Their distribution (Fig. 6) can be related to a number of gross environmental factors particularly precipitation, temperature, substrate, proximity to the coast and altitude.

It is important to note that the distribution map and the description of the vegetation is based on a survey done some 35 years ago (Acocks, 1953). The boundaries of the various types are, therefore, not reliable, but merely indicate the broad divisions within the south-western corner of South Africa. A summary of the vegetation types with rainfall and altitude ranges, main substrate types, and some physiognomic characteristics are given in Table 6.

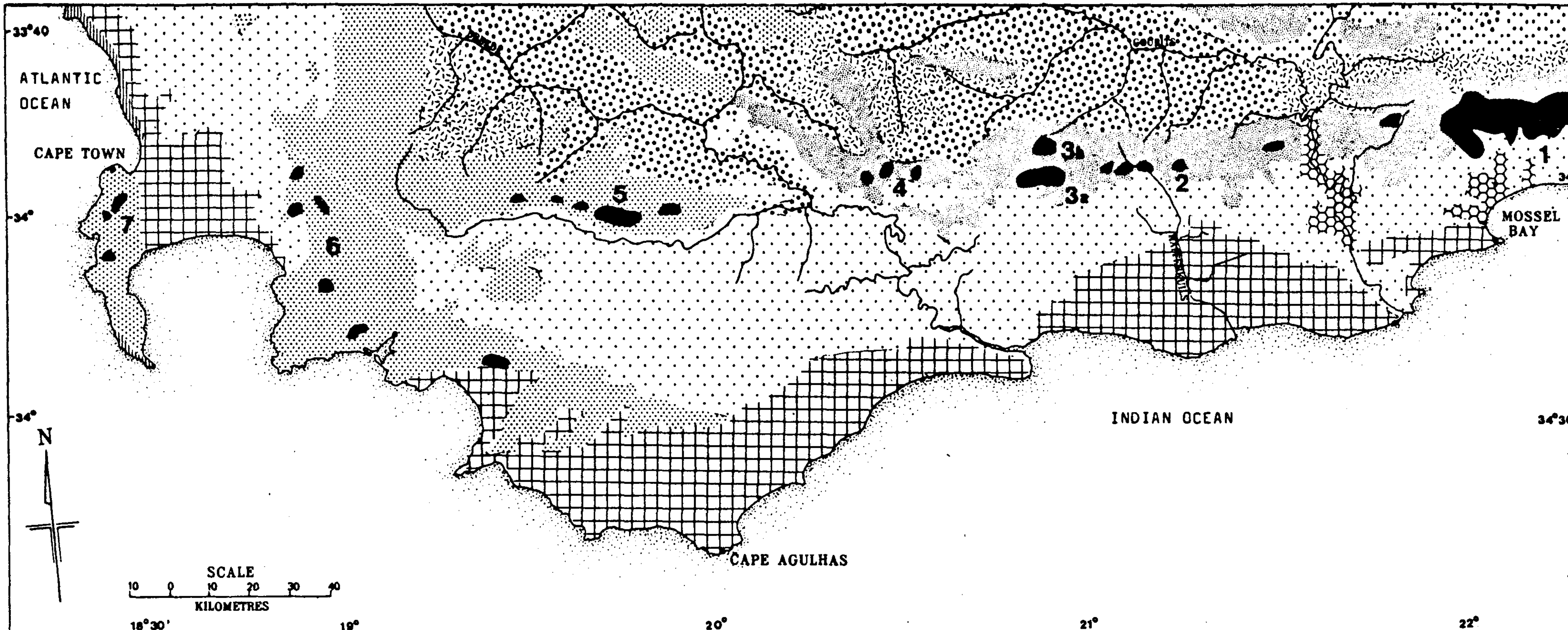


FIG. 6 Distribution of Vegetation Types in the study area (Acocks, 1953).

KEY

VEGETATION TYPE	FOREST COMPLEXES
Macchia (Fynbos)	1 Jonkersberg
False Macchia (Fynbos)	2 Riversdale
Coastal Rhenosterbosveld	3a Grootvadersbos
Coastal Macchia (Fynbos)	3b Boesmansbos
Gouritz River Scrub	4 Swellendam
Mountain Rhenosterbosveld	5 Riviersonderend
Karrooid Brokenveld	6 Hottentots Holland
Strandveld	7 Cape Peninsula
Succulent Mountain Scrub	
Indigenous Forest (x10)	

3.1 KAROO AND KARROID TYPES

3.1.1 Gouritz River Scrub (Veld Type 23e)

This vegetation is found in the river valleys in the east of the study area (Fig. 6) and consists of dense, semi-succulent, thorny scrub, about 2m high in which arborescent aloe species are common. It occurs largely on the Bokkeveld Shales which are rich in plant nutrients and the cover is high (70 - 90%). At the upper altitudinal limits it merges into Fynbos (Veld Type 70) and Mountain Rhenosterbosveld (Veld Type 43), and although it contains a number of trees, only a few are constituents of the evergreen Langeberg forests (e.g. Euclea undulata, Cassine aethiopica, Maytenus heterophylla and Carissa bispinosa).

3.1.2 Succulent Mountain Scrub (Veld Type 25)

This is essentially a dense scrub dominated by the succulent-leaved shrub Portulacaria afra (spekboom) with more-or-less the same species composition of the Gouritz River Scrub, though it tends to lack the thorniness of the latter. This veld type is also found in the eastern section of the study area on shales at an altitude of between 300 - 600m in the Little Karoo. The total cover varies between 60 - 75% with the scrub being as high as 3m tall in places. Rainfall is low (250 - 300mm) and thus no evergreen forests

Table 6: Summary of selected environmental and physiognomic data for the vegetation types in the study area.

Vegetation Type	Rainfall Range (mm)	Altitude (metres)	Geological Substrate	Physiognomy of Vegetation	± Height (metres)	% Projected Canopy Cover
Gouritz River Scrub	250-800 Riverine	0-250	Bokkeveld Shale	Dense semi-succulent Spinescent Scrub	0,5-3,0	70- 90
Karroid Broken Veld	200-400	200-700	Bokkeveld Shale	Sparse Karroo semi-succulent Scrub	0,2-1,0	15- 50
Succulent Mountain Scrub	250-300	300-650	Bokkeveld Shale	Dense succulent Scrub	0,5-3,0	60- 70
Strandveld	50-300	0-20	Recent sands	Succulent shrubland	0,1-1,0	50- 90
Mountain Rhenosterbosveld	300- 1000	300-800	Bokkeveld and TMS Shale	Low scrub	0,2-1,5	60- 90
Coastal Rhenosterbosveld	300-500	0-300	Bokkeveld Shale	Dense thorny scrub	0,5-2,0	60
Coastal Macchia	300-500	0-300	Recent sand Limestone	Dwarf and scrub Heath	0,2-1,5	50- 90
Macchia	250	--	TMS and shale	Mountain heath	0,2-3,0	50- 90
False Macchia	250	--	TMS and shale	Mountain heath	0,2-3,0	50- 90
Forest	600	--	Shale TMS	Tall evergreen Closed forest	8,0-30,0	90

are present. Typical trees beside the spekboom include *Euclea undulata*, *Rhus lucida*, *Grewia robusta*, *Maytenus undata* and *Polygala myrtifolia*. Only *Euclea undulata* and *Rhus lucida* are found in the forests and then they are usually on the margins.

3.1.3 Karroid Broken Veld (Veld Type 26)

This vegetation occupies rocky, hilly country at elevations ranging from 300 - 650m and receiving 200 to 300mm of rainfall distributed evenly through the year. It occurs in the Little Karoo to the north of the Langeberg mountains and ranges from sparse semi-succulent scrub with a cover of 15 to 50%, to clumped more dense scrub on hills. The *Mesembryanthaceae* are very prominent in this type; Acocks (1953) lists 44 species which does not even include all the common ones.

The vegetation height generally ranges from 0,2m to 1m, but reaches up to 2m high along river banks. Typical trees along the streams are *Acacia karoo*, *Rhus lancea*, *Salix capensis* and *Buddleja saligna*. Only the last mentioned species is found in the forests of the Langeberg and then mainly on the margins.

3.1.4 Strandveld (Veld Type 34)

This vegetation is found on recent sands on the low coastal plains in the west (see Fig. 6), and receives 50 - 300mm rainfall per annum mostly in winter. It has two variations, one being dense (80% cover) and semi-succulent up to 1m tall and related to Gouritz River Scrub, and the other is shorter (0,2m - 0,5m), less dense (50% cover) and contains elements of macchia. In places where the taller variation is less xerophytic it becomes transitional to Dune Forest. The Dune Forest dominants are *Sideroxylon inerme*, *Rhus glauca*, *Maytenus heterophylla*, *Myrsine africana*, *Maurocenia frangularia* and *Linociera foveolata*. The last four species mentioned can be constituents of the evergreen forests.

3.1.5 Mountain Rhenosterbosveld (Veld Type 43)

This Veld Type is included in the Karroid Types because of its former grassy nature. *Merxmuellera stricta* is the chief relic but today the grasses have been replaced by karroid shrubs. This type does not include all the Rhenosterbosveld occuring on the mountains, only that false karroid part of it where the Rhenosterbos (*Elytropappus rhinocerotis*) appears to be the dominant.

Some areas shown as False Fynbos (Fig. 6) are in fact Rhenosterbosveld, but here the Rhenosterbos is an invader

(Acocks, 1953). The vegetation is generally low (0,2 - 1,5m) with between 60 and 90% cover and no important tree species. It is found almost exclusively on Shales, between altitudes of 300 and 800m where the rainfall exceeds 300mm per annum.

3.2 SCRUB TYPES

3.2.1 Coastal Rhenosterbosveld (Veld Type 46)

This occurs in two blocks, one on the coast plain in the west and one on the coast plain in the south (Fig. 6). Both areas comprise undulating country with a clayey soil which today is extensively cultivated, leaving only a few poor relics. According to Acocks (1953) the vegetation appears to have been dense (greater than 60% cover) thorny scrub with *Olea africana* and *Sideroxylon inerme* being the dominant trees. Scattered individuals of these two species still occur today on the plains south of Swellendam.

The lower parts of the valleys in the southern block may have had a drier, semi-succulent scrub (Acocks, 1953), while the upper parts of the valleys probably had a scrub which was transitional to forest. The following tree species which also occur in the forests are found here : *Buddleja saligna*, *Rhus lucida*, *Pterocelastrus tricuspidatus*, *Olea africana* and *Maytenus heterophylla*. The western section consists mainly of Rhenosterbosveld with many grasses also being present. The rainfall in both sections ranges between

300 and 500mm per annum.

3.2.2 Coastal Macchia (Veld Type 47)

This vegetation occurs on sand and limestone in the west and south coastal belts up to 300m a.s.l. It appears to lack the thorniness and semi-succulence of the scrub of the heavier soils. Acocks (1953) suggests that both areas have climax vegetation type of open grassy scrub with fynbos species always being present. Scrub forest up to 10m high is still to be found, mainly on the south coast. The principal tree species found, most of which occur in the forests of the study area too, are : *Cassine peragua*, *Rhus lucida*, *Maytenus heterophylla*, *Rhus tomentosa*, *Pterocelastrus tricuspidatus*, *Linociera foveolata*, *Myrsine africana*, *Sideroxylon inerme*, *Olea africana* and *Euclea racemosa*.

3.3 SCLEROPHYLLOUS BUSH TYPES

3.3.1 Macchia (Veld Type 69) and False Macchia (Veld Type 70)

Acocks (1953) dealt extremely briefly with the Sclerophyllous Bush Types dividing them into two types : Macchia and False Macchia. The Macchia, known as the fynbos, is the southern vegetation, different in origin and nature to the tropical vegetation of South Africa (Acocks, 1953; Levyns, 1964), but today very mixed with it. False Macchia according to

Acocks (1953) is indistinguishable from Macchia but contains indications that in its natural state would have been transitional from sourveld to Macchia. There is as yet no detailed map of the distribution of Macchia types in the study area, the most recent account being by Taylor (1978) and this is of a descriptive nature. He has divided the fynbos into three sub-sections : Mountain Fynbos, Arid Fynbos and Coastal Fynbos, and has identified the following physiognomic characteristics :

(a) the restioid element, which is invariably present and comprises wiry, aphyllous, hemicryptophytes of the Restionaceae and some Cyperaceae,

(b) the ericoid element, which comprises dwarf and low, evergreen ericoid shrubs. A frequent but not constant feature is a component of taller broad sclerophyllous shrubs (the proteoid element).

The Mountain Fynbos is 0,2 - 2,5m tall and even taller on wet sites or where it contains a tall proteoid component. Cover may vary from 50 to 85%, approaching 100% on wet and mature sites. The Fynbos occurs mainly on Table Mountain Sandstone, quartzite and Bokkeveld Shale, usually at higher elevations (above 300m) and where the annual precipitation exceeds 250mm.

Within his Montane Fynbos type Taylor (1978) includes what he calls Hygrophillous Fynbos where plentiful soil moisture is a unifying factor. Were it not for fires the normal plant succession on these sites would lead to forest. Indeed, Phillips (1931) includes Hygrophillous Macchia in a seral stage to the formation of evergreen forest at Knysna. This succession has been observed in some Fynbos areas at a number of sites (Thunberg and Kotze, 1940; Taylor, 1955; van der Merwe, 1966; Werger, Kruger and Taylor, 1972; Campbell and Moll, 1977; McKenzie, Moll and Campbell, 1977). Typical evergreen forest trees found in the taller seral stages are : *Maytenus accuminata*, *M. heterophylla*, *Hartogia schinoides*, *Cassine peragua*, *Ilex mitis*, *Cunonia capensis*, *Halleria lucida*, *Podocarpus latifolius*, *Rapanea melanophloeos*, *Kiggelaria africana* and *Linociera foveolata*.

The temperate evergreen forests are not discussed in this section as they are dealt with in detail later.

3.4 PHYTOGEOGRAPHY OF THE FORESTS

Only relic patches of forest remain today and the situation of the larger patches relative to the aforementioned vegetation types are shown in Fig. 6. These forests occur as small or large patches on the foothills, slopes, kloofs and streams of the major mountain ranges in the study area (see Photo 2). They occur on granite, shale and sandstone in regions where the annual precipitation exceeds 650mm and the site is fairly well protected. The larger and more diverse forests in terms of structure and species composition occur in the eastern half of the study region (Fig. 6).

Various research workers have referred to the relic evergreen forests of the South-western Cape as being related to the forests of the Southern Cape Coastal belt (Sim, 1907; Laughton, 1937; Wicht, 1945; Taylor, 1955; Von Breitenbach, 1974 and Taylor, 1978). White (1978) suggests that these forest islands are largely composed of tree species belonging to the Afromontane element. He grouped the forests of South Africa into five local systems, namely : Transvaal, Natal-Transkei, Cape Province east of Knysna, Knysna and the forest enclaves west of Knysna. He compared these five regions in an analysis based on 51 species of which the taxonomy, ecology and distribution were sufficiently documented. There is a gradual tailing off of species numbers from the Transvaal system to the enclaves of the South-western Cape. The forests of the South-western Cape, although somewhat impoverished, contained half of the entire species complement analysed by White. This drop off in species numbers is also evident in the forests of the study area, the most westerly forest relics containing fewer species than those in the east.

For ease of comparison the forests of the study region have been divided into seven complexes based mainly on observations of structure and species presence or absence. These are, from east to west, Jonkersberg, Riversdale, Grootvadersbos (including Boesmansbos), Swellendam, Riviersonderend, Hottentots-Holland and the Cape Peninsula complexes. Most are separated from their nearest neighbour by breaks in the mountain chain (see Fig. 2 and Fig. 6). All the major tree and woody shrub species are included in Table 7 which shows the distribution of the species within the seven forest complexes recognised. Included in the Table are the species which White (1978) compared for the five local (South African) Afromontane systems. Both species of Pterocelastrus are tabulated for the study region, whereas White only included the genus. Gonioma kamassi is also included in the table although it is a species correctly described by White as falling outside the forests of the south-western Cape. It is restricted to the Jonkersberg complex which falls within White's (1978) Knysna system. Only species which were recorded in the survey are considered, although the Jonkersberg forest complex contains many more species not found in the other six complexes.

Table 7 is self-explanatory, and it shows the gradual drop off in species from east to west. Of the 51 species considered, 30 are common throughout the seven complexes.

Table 7: Distribution of 51 major woody species in the seven forest complexes of the study region. Species considered by White (1978) are marked with an asterisk.

SPECIES COMPLEX	JONKERSBERG	RIVERSDALE	GROOTVADERSBOS	SWELLENDAM	RIVIERSONDEREND	HOTTENTOTS HOLLAND	CAPE PENINSULA
*Gonioma kamassi	+						
Trichocladus crinitus	+						
Cassine papillosa	+						
Trimeria grandifolia	+						
Lachnostylis hirta	+	+					
Rhamnus prinoides	+	+	+				
Sparrmania africana	+	+	+				
Burchellia bubalina	+	+	+				
*Nuxia floribunda	+	+	+				
Buddleja saligna	+	+	+				
Piper capense	+	+	+				
Rothmannia capensis	+	+	+	+			
*Podocarpus falcatus	+	+	+	+			
Brachylaena glabra	+	+	+	+			
Canthium obovatum	+	+	+	+			
*Calodendron capense	+	+	+	+			
Carissa bispinosa	+	+	+	+	+		
Cassinopsis ilciflora	+	+	+	+	+		
*Platylophus trifoliatus	+	+	+	+	+		
Laurophyllous capensis	+	+	+	+	+	+	
Maurocenia frangularia					+	+	+
*Pterocelastrus rostratus	+	+	+	+	+	+	+
*Apodytes dimidiata	+	+	+	+	+	+	+
*Canthium mundianum	+	+	+	+	+	+	+
*Canthium ventosum	+	+	+	+	+	+	+
*Cassine peragua	+	+	+	+	+	+	+
*Cunonia capensis	+	+	+	+	+	+	+
*Curtisia dentata	+	+	+	+	+	+	+
*Diospyros whyteana	+	+	+	+	+	+	+
*Halleria lucida	+	+	+	+	+	+	+
*Ilex mitis	+	+	+	+	+	+	+
*Kiggelaria africana	+	+	+	+	+	+	+
*Linociera foveolata	+	+	+	+	+	+	+
*Ocotea bullata	+	+	+	+	+	+	+
*Olea capensis	+	+	+	+	+	+	+
*Olinia ventosa	+	+	+	+	+	+	+
*Podocarpus latifolius	+	+	+	+	+	+	+
*Rapanea melanophloeos	+	+	+	+	+	+	+
*Scolopia mundii	+	+	+	+	+	+	+
*Pterocelastrus tricuspidatus	+	+	+	+	+	+	+
*Celtis africana	+	+	+	+	+	+	+
Hartogia schinoides	+	+	+	+	+	+	+
Maytenus accuminata	+	+	+	+	+	+	+
Scutia myrtina	+	+	+	+	+	+	+
Grewia occidentalis	+	+	+	+	+	+	+
Maytenus heterophylla	+	+	+	+	+	+	+
Clutia pulchella	+	+	+	+	+	+	+
Virgilia oroboides	+	+	+	+	+	+	+
Olea africana	+	+	+	+	+	+	+
Cussonia thyrsiflora	+	+	+	+	+	+	+
Maytenus oleoides	+	+	+	+	+	+	+
Number of species	50	46	45	39	35	32	31
Percentage of total	98,03	90,2	88,2	76,5	68,6	64,7	60,8
Common to all complexes	58%						

The Cape Peninsula complex in the south-westlacks 20 species which are present in at least one of the other complexes further east. The most interesting absence is probably that of Platylophus trifoliatus (Witels), for this species along with the only other member of the Cunoniaceae in Southern Africa, Cunonia capensis, is considered to have austral origins (Adamson, 1948; Good, 1964). The family occurs essentially in the forests and streamlands of many southern hemisphere land masses. Sixteen genera are more-or-less narrowly endemic, and much concentrated in New Guinea and Australasia. Only one genus, Weinmannia is very widespread. Considering the suggested austral origin it is surprising that Platylophus is not found in the Cape Peninsula forests which are the most southerly of the forest complexes. Another taxa with a suggested austral origin is the Podocarpaceae (Levyns, 1964). Podocarpus falcatus is only found from Swellendam eastwards. Suggestions as to the possible existence of Podocarpus falcatus on the Cape Flats between the Hottentots Holland and Cape Peninsula complexes in the past are discussed in Section 4.3. Most of the other species in the Table 7 have supposedly boreal origins (Levyns, 1964; Von Breitenbach, 1965; Van Zinderren Bakker, 1973; White, 1978) and their absence from the more westerly complexes is more understandable. One species, Maurocenia frangularia is restricted to the three most western complexes although it belongs to the family Celastraceae with supposedly northern origins (Van Zinderren Bakker, 1973).

Although 58% (i.e. 30) of the species present in Table 7 occur throughout the study area, the structure and communities of the forests are often profoundly affected by the discontinuous species (see Table 8 and Chapter VI). An example of this is Rothmannia capensis, which is confined to the four most eastern forest complexes and is often the dominant understorey and sub-canopy tree species in medium moist and dry forests. The forests further west (i.e. Riviersonderend, Hottentots Holland and Cape Peninsula complexes) appear to have a lack of any one species dominating the sub-canopy and understorey layers of medium moist and dry forest. Similarly, in the drier forests of the Jonkersberg complex Trichocladus crinitus (onderbos) is dominant in the understorey while further west, as far as the Riviersonderend complex, a number of species are found in the understorey layer of which Carissa bispinosa is the principle shrub, although it is largely confined to the field layer (less than 1m high). The Hottentots Holland and Cape Peninsula complexes have no dominant understorey species; Carissa bispinosa does not occur here.

The northern origin of most of the taxa as well as a number of other factors (e.g. size of forest, geological substrate, faults and climate and edaphic effects), could explain the relative lack of species richness in the forests of the study region and the decrease in species numbers from the eastern complexes to those in the west.

Three floras come into contact in the study area : the Karoo, Forest and Cape floras (Werger, 1978). The ecological relationships between these floras has not yet been quantified, but a study by Levyns (1950) on hills near Ladismith indicated that moisture availability played an important part between the Cape and Karoo floras. The lack of climatic fluctuation (together with water availability) plays an important role in the balance between the Forest and Cape floras (Levyns, 1952). All three floras are thought to be of considerable age (Levyns, 1938; 1957; Adamson, 1948), because :

(a) the Cape and Karoo floras are very rich in species,
(b) both contain many endemics,
(c) the Cape and Forest floras show a remarkable absence of species dominance,
(d) the Cape flora shows a great local variation, and
(e) especially in the Cape flora, many species which are phylogenetically unrelated, show evolutionary convergence.

Numerous attempts have been made to determine the origins and relationships between these three ancient floras (Bews, 1921; Levyns, 1950; 1952; Good, 1964). The most common theory being related to the expansion and contraction of the floras in dry and wet epochs. There is evidence to suggest that the forests themselves were much larger and this is discussed in the following Chapter.

CHAPTER IV

HISTORICAL AND BIOTIC FACTORS PERTAINING TO THE FORESTS

It has already been mentioned that the forests once occupied a much greater area than they do today, but the exact extent of these forests would be extremely difficult to estimate. There are accounts by early travellers, but they are all of a descriptive nature and conflicting guestimates as to the size of the forests are found in the literature (Theal, 1882; Sim, 1907). There are three main factors to consider when discussing the former extent of the forests, these are climate, fire and exploitation. In the long term climate and possibly fire were the two most important factors, while during the last couple of centuries fire and exploitation were the most significant factors causing a reduction in the extent of the forests.

Clements (1936) states that "no student of past vegetation entertains a doubt that climaxes have evolved, migrated and disappeared under the compulsion of great climatic changes from the Paleozoic onwards", but he is also insistent that they persist through millions of years in the absence of such changes and the disturbance of man. Tansley (1929) considers climatic successions to be progressive or retrogressive. Pyric and anthropogenic successions are primarily retrogressive and sometimes cataclysmic, and anthropogenic succession can be progressive. Change, therefore, will be the result of different causes, some advantageous, others detrimental, especially when a particular vegetation type is under consideration.

Changes as a result of the interference of modern man operate mainly through destruction of the climax. Two significant causes with respect to climax communities in the Cape appear to be the increased incidence of fire and the introduction of alien species (Adamson, 1927; Taylor, 1978). Exploitation, often closely linked with fire, allows the forest canopy to be opened and alien species can then compete more effectively with indigenous forest species. This is particularly evident in the study area where Acacia melanoxylon (blackwood) has often become the dominant canopy species in forests (e.g. Orange Kloof, Table Mountain).

With this somewhat brief introduction it is proposed to deal with the three main causes of the contraction of forested areas under the following headings : history and exploitation, fire and climate.

4.1 HISTORY AND EXPLOITATION

From the writings of Theal (1882) in which he described the policies and actions of the first settlers in the Cape, it is obvious that the extent of the indigenous forest in the south-westernCape was once much greater. The destruction of the forests of the Cape Peninsula was completed in the first fifty years of settlement at the Cape, starting in 1652 (Sim, 1907; Spilhaus, 1950). However, these forests could not have been too extensive as the early governors of the Cape showed a keen interest in tree planting (Laughton, 1937). In 1689 an order was given on all proprietors of land to plant a hundred young oaks on each grant of land, and the introduction of *Pinus pinaster* goes back to the beginning of the 18th century (Laughton, 1937).

Because of the depletion of the Peninsula forests, onder-coopman van Putten and the gardener Jan Hartogh were instructed to investigate the forests of Riviersonderend in 1712 (Sim, 1907; Immelman, Wicht and Ackerman, 1973). These men reported that they found large numbers of trees suitable for timber and wagonwood, and estimated that the supply could last a hundred years. This was extremely optimistic as by 1776 practically no timber or wagonwood was left in the forests of Riviersonderend (Hartwig, 1973). As an example of exploitation after this date the following record of timber extracted from these forests between September 1787 and August 1793 (Hartwig, 1973) is given :

1594	wagon-felloes
2347	wagon spokes
124	naves
112	wagon axles
128	pivot plates
54	horse-cart front forks

70	oxwagon afterquides	
75	draught poles	
7	bogie centres	
4	long wagons	
126	sawn rails	
80	"Malwagen bome"	)
4	"Malwagen felloes"	)
10	coach felloes	)
13	coach axles	)
14	coach naves	)
3	coach longwagons	)
2	coach draughtpoles	) for the artillery
89	naves	)
29	axles	)
516	felloes	)
1129	spokes	)
24	draught poles	)

It is obvious from the above figures that vast areas of forest must have been destroyed to get these finished articles, and this <u>after</u> all the <u>good</u> timber had already been removed. One can only speculate on the amount of wood removed and the damage caused in the previous seventy years of exploitation.

The forests of Swellendam and Grootvadersbos were exploited from 1746, when Swellendam was founded (Sim, 1907).

Grootvadersbos has been described by Robertson (1924) and Taylor (1955) as the most noteworthy remnant in the study area. Taylor (1955) estimated the size of Grootvadersbos to be about 500 hectares. Conservation measures probably stopped this remnant from being completely stripped of all wood.

The first trek-boers probably reached the George-Knysna region in 1711 (Hartwig, 1973), but is was not until 1772 that the forests were exploited (Phillips, 1931). Four years after this date, in 1776, it was reported that practically no timber or wagonwood was left in the Company's forests at Riviersonderend and Swellendam, and that Grootvadersbos had been very nearly stripped of useful timber (Hartwig, 1973).

Conservation measures were not lost sight of from the beginning of settlement at the Cape, but they seemed to have had little or no effect on exploitation. On the second of October, 1658, there was a "proclamation against the cutting of wood in the company's forests. Freemen were forbidden to sell firewood to lime or brick-burners, or to foreigners without notice. Wood-cutting at Bush River was prohibited." (Sim, 1907; Laughton, 1937).

A proclamation of 1792 (Sim, 1907) contains "regulations respecting woodcutting. Prohibition against cutting timber in the forests of Riviersonderend, Grootvadersbos and Outeniqualand".

It would seem that in spite of regulations such as the above with regard to woodcutting and those concerning burning of the veld, the authorities were unable to enforce these measures. The complete destruction of some of these forests was probably a gradual process which continued well into the present century (see Photo 3 and 4).

No mention has been made of the influence of the indigenous peoples on the forests prior to the arrival of the Europeans. However, there is little evidence to suggest that they used the forests extensively, as they were largely pastoralists (Schweitzer and Scott, 1973; Klein, 1974). They probably did, however, burn the veld for grazing which could have affected the forest margins.

4.2 FIRE

Vasco da Gama, in 1497, referred to the south-western Cape as Terra de Fume on account of dense smoke seen along the coast (Sim, 1907). This, it appeared, was caused by the Hottentots who, in order to benefit from the resultant, albeit shortlived, lush pastoral growth for their livestock, would burn the veld. This method was used by the immigrant farmers from Europe in later years (Clark, 1959).

Historical accounts of fires include such catastrophes as the fire of 1869 which devastated thousands of hectares of natural forest from Swellendam eastwards to Humansdorp (24^{o} 45'E, 34^{o} 00'S), an area 650 kilometres long and anything from 25 to 240 kilometres wide (Wicht, 1945). Another enormous fire in the middle of the eighteenth century produced a smoke pall 190 kilometres long and some 12 kilometres wide, which clouded the district for several days (Sim, 1907). Fires such as these must have caused havoc and surely destroyed many hectares of forest thus reducing the area of forest.

Many research workers now recognise that fire is extremely important in the ecology of the fynbos vegetation (Taylor, 1978; Kruger, 1978). It is not the intention to deal with fire in fynbos in any detail here, most of the current thought on the subject being summarised by Taylor (1978), Kruger (1978) and Moll, McKenzie and McLachlan (1978). The latter workers suggested that the relative lack of a major tree component in the fynbos, when compared to other mediterranean systems, is due to the elimination of a tree or tall shrub element by too frequent burning.

The general ecology of the indigenous forests in the study area is not related to fire except where forests have been destroyed by fire in the past (see Photo 5). However, it is seldom that forests are burnt out completely. It is usually only when the forest has been greatly modified by overexploitation that fire makes great inroads into it (Sim, 1907; Henkel, 1912). Sim (1907) in fact states that it is seldom that the condition of virgin high forest is such as to make it possible for fire to pass through, or to do much damage. It is only when the margins have been destroyed that the fire can actually make inroads into the forests. Most of the forests in the study region have little or no margin to them, the typical marginal vegetation having been replaced by firebreaks. Where there are no firebreaks, wildfires and those fires used by the local land owners to burn the veld have gradually pushed back the forest margins to places where there is some form of natural physical barrier against further fire penetration.

The occurrence of fires causing great damage lends support to the theory that the forests and forest remnants today are relatively immune to damage, because they now occupy those moist or rocky sites to which fires do not rapidly spread. This is true for most of the forest patches in the western section of the study area and it is only in the eastern section of the study area where forests of considerable size are found. However, even on the protected sites the forest may still be affected by fire. McLachlan and Moll (1976) estimated that a fire in the forest in Woody Ravine, Table Mountain, eliminated between 5000 and 10000 trees.

Once the succession has been set back (e.g. overexploitation and the elimination of the marginal communities by fire), fully developed forest is in fact unlikely to recolonize the area, because not only will the flora have been destroyed, but the humus rich soil, essential to forest growth will have been destroyed also. To rebuild this highly organic soil takes decades of protection.

Most of the largest remnant forest patches remaining today are under the jurisdiction of the Department of Forestry. One of the Department's major management objectives is water conservation, and the vegetation cover must be such that sufficient water can run-off. Van der Zel and Kruger (1975) made a study of the effect of fynbos cover on streamflow at Jonkershoek Research station. They showed that protection from fire of this upland fynbos catchment resulted in a one per cent decrease in streamflow per year of protection; the reduction being ascribed to increased transpiration and interception losses arising from an increase in phytomass. The effect of protection will not be equal in all catchments because the vegetal cover may be less dense. Where the climate is favourable, the precipices fewer and the soil deeper (so that a luxuriant vegetation develops), an even greater reduction can be expected. It is in areas such as these where most of the remnant forest patches occur and could be expected to expand in time. However, with the increasing demand for water in the future, which is enhanced by frequent burns, it is unlikely that the forests will ever be given the chance to expand. It is significant that a phytosociological study (McKenzie, Moll and Campbell, 1976 and 1977) in Orange Kloof, Table Mountain, indicated that the scrub vegetation of this catchment showed greater affinity to the forest flora than the fynbos. The importance lies in the fact that although the fynbos elements of this scrub association, which had been protected from fire for over thirty years, could be said to be moribund (thus reducing waterflow), the forest elements were actively invading the scrub. It is highly likely that the majority of the valley will be covered by indigenous scrub forest in half a century's time.

In conclusion it is sufficient to say that fire has been an important biotic factor in the study area for centuries, and the size of the forests have definitely decreased due to natural and man induced fires especially in areas that have suffered overexploitation. The forest remnants left, although occupying sites largely protected from fires, could expand if the fynbos in the peripheral areas are protected from fire.

4.3 CLIMATE

Von Breitenbach (1974) refers to the remnant forest patches as living witnesses to great vegetation movements which have taken place in Southern Africa in response to climatic fluctuations over tens of thousands of years. Although evidence to suggest that there have been great climatic changes is gradually accumulating, very little is known about the effect these climatic fluctuations have had on the vegetation. One can only speculate and hypothesize as to the contraction and expansion of the forests during dry and wet epochs. This account will briefly consider some of the evidence which relates to possible climatic changes and their effect on the forests.

Firstly, there have not been any major catastrophes at the Cape since the evolution of the flowering plants (Levyns, 1964). Rainfall fluctuations have occurred, especially during the Pleistocene, and it has been postulated that during the pluvials rainfall was some 140% above the present, and during the interpluvials 60% below (Van Zinderren Bakker, 1969). The present character of the fynbos, in particular the degree of speciation, is the product of processes operating throughout the Pleistocene including the effect of long term (100 000 year) cyclic changes in temperature and hence available moisture. The present Holocene climate (the last 10 000 years) is not the norm for the Pleistocene, as the zone has experienced repeated, longer cooler intervals (Van Zinderren Bakker, 1974).

Examples of hypothetical vegetation maps, based on a "Vegetation Map of Africa South of the Tropic of Cancer" by Keay (1959) and assuming a variation of from 60% of current precipitation to 140% during wet epochs are given by Cooke (1962). These ignored any superimposed temperature variations and probably overemphasize the degree of rainfall during the Pleistocene, but do indicate that the forest flora was probably widespread in the eastern section of the study area during wet epochs.

Supporting evidence of major climatic changes in the past comes from archaeological and pollen studies (Martin, 1955; Klein, 1971; Schalke, 1973; Hendey, 1975 and 1976; Tankard, 1976). However not all the evidence is conclusive. Van Zinderren Bakker (1974) believes that the evidence for the occurrence of Podocarpus forests on the Cape Flats (Schalke, 1973) is not convincing due to a number of factors. Firstly, the percentage of Podocarpus pollen was very low, and secondly the large trunks of Podocarpus found on the flats (Adamson, 1951) could have been transported by ocean currents. Even a high percentage of pollen for a species like Ilex mitis (Schalke, 1973) is not convincing as to the former distribution of forests because this species occurs along rivers and in other moist areas presently not covered by forests.

With the Pleistocene glaciations changes in sea level occurred, alternatively covering the coastal flats and uncovering the continental shelf (Hamilton and Cooke, 1965). Consequently large areas of unoccupied land were created which could be colonised from the mountains, which had been in existence since the Triassic (du Toit, 1954). This suggested colonization has led Rourke (1972) to imply the origin of new species (e.g. a number of Leucospermums) from a parent species invading a vacant niche. Such postulations are, however, only related to species other than the forest tree flora and it is doubtful whether the forests migrated onto the exposed shelf. Even if the climatic factors were right, the edaphic factors could preclude forest development.

All the evidence mentioned above is too fragmentary to give an adequate appreciation of vegetation movements, especially of the forests. In fact Van Zinderren Bakker (1967) states that as the winds and ocean currents have not changed fundamentally during the past 70 000 years, the changes in climate have been rather of a quantitative nature.

CHAPTER V

PHYTOSOCIOLOGICAL METHODS

5.1 INTRODUCTION

Few plant ecological studies have been completed on the forests of the region under consideration, and those that have been done, have been limited to descriptive accounts and species lists from a few isolated areas (Sim, 1907; Robertson, 1924; Adamson, 1927; Muir, 1929; Thunberg and Kotze, 1940; Spilhaus, 1950; Taylor, 1955 and 1961; Heyns, 1957 and Boucher, 1969). In the last five years only three phytosociological studies, which have included forest, have been carried out in the South-western Cape. Werger, Kruger and Taylor (1972) studied fynbos vegetation and two "forest" releves in the Jonkershoek catchment near Stellenbosch; McKenzie, Moll and Campbell (1977) worked on the fynbos, scrub and forest vegetation of Orange Kloof, Table Mountain, and Campbell and Moll (1977) published a phytosociological study of the forests of the Cape Peninsula, with special reference to the forests of Table Mountain. A lot of published data pertaining to the large areas of forest near Knysna, just east of the study area, have been completed; work of Phillips (1931), Laughton (1937) and von Breitenbach (1972), being the best known. Data from more recent surveys of the Knysna forests by the Department of Forestry have yet to be published.

In South Africa as a whole, little attempt has been made to classify or group the forests (quantitatively or qualitatively - except White, 1978). Most of the studies have concentrated on local areas, in particular the Natal and Knysna regions, with little published work of forests elsewhere (Rycroft, 1944; Killick, 1958 and 1962; Cooper and Moll, 1966; Moll and Haigh, 1966; Edwards, 1967; Moll, 1968 a and b, 1969, 1972; Moll and Woods, 1971; van der Schiff and Schoonraad, 1971; von Zinderren Bakker, 1973; Rogers and Moll, 1975).

The indigenous forests of the South-western Cape are small isolated relics and an understanding of their floristic relationships is important in view of their rarity and conservation future. The floristic relationships of these forests is of added importance considering that major climatic and physiographic changes transgress the region.

In order to classify the forests the Braun-Blanquet or Zurich-Montpellier system (Braun-Blanquet, 1964; Shimwell, 1971; Werger, 1974 and Mueller-Dombois and Ellenberg, 1974) was used.

The method consists of a sampling and a synthetic phase. The sampling phase includes selecting representative homogeneous plots of a certain minimum size in the vegetation of the area to be surveyed; species recorded are given a cover-abundance rating and optionally, a value for sociability. The samples are then entered into a matrix from which the vegetation units are extracted. These units are interpreted ecologically and ranked in a hierachy. The techniques of this approach as outlined by Werger (1973 a and 1974) were followed with a number of modifications which are discussed under the appropriate sections.

5.2 SAMPLING

5.2.1 Site Selection

The basic aim of the sampling procedure employed in the survey was to locate "true" forest sites. Many workers have attempted to define forest clearly. According to Fosberg (1961) it is simply closed woody vegetation 5m or more tall, while Phillips (1970) defines it as a multi-storeyed (3 - 6) community of trees usually in terrain of higher atmosphere humidity and rainfall or less often, upon soils of higher available moisture content within a less humid climatic subregion. For the purposes of the present study forest is considered as a multi-stratified, closed canopy plant community dominated by trees, with more than two woody plant strata and comparable in structure with the forests in the Southern Cape (Von Breitenbach, 1972).

Forest sites for sampling were located by using 1:50 000 topographical maps (Trigonometrical Survey Office, 1962) and aerial photographs. An attempt was made to choose forest sites that were at least 5 ha in extent, to ensure that a representative area of forest was sampled. The forest stand at each site was chosen so as to avoid marginal zones and areas heavily exploited or invaded by alien vegetation.

Stands were thus chosen subjectively in accordance with the community unit theory which postulates that vegetation consists of natural entities generally contacting each other along narrow boundaries (Braun-Blanquet, 1932; Whittaker, 1960; Mueller-Dombois and Ellenberg, 1974). This concept fits in with Braun-Blanquet's (1932) ideas on the nature of the community. He regarded the plant community as a basic unit of vegetation classification, as the species is considered the basic unit in taxonomic classification of organisms.

Although there is no fundamental objection against using stratified random, random, or systematic sampling for the Braun-Blanquet technique, the nature of the vegetation and the object of the study precluded the use of any form of randomization.

5.2.2 Representativeness

According to Werger (1974), stands to be sampled should be selected in such a manner so that each is representative of the vegetation of which it is part, and that each plot sampled therein should yield a more-or-less typical description of that vegetation in terms of both floristic composition and structure. Although the forest sites surveyed are from one vegetation type, their distances apart and thus their floristic and structural complexity allowed for local differences. The choice of representativeness of sample stand thus varied from site to site depending on local structure (horizontal and vertical), floristic composition and various physical factors including the actual size of the forest patch.

5.2.3 Minimal area and Plot size

In sampling the community it is important that as many of the species as possible are recorded, and this can be achieved by determining a certain minimal sample size in which the community can represent itself (Shimwell, 1971; Werger, 1974; Mueller-Dombois and Ellenberg, 1974). Such an area is assumed to be the "optimal" plot size in terms of information content. Any smaller area will not contain the true characters of the community and to sample any larger area would be a waste of time and effort. However, the assumption is not necessarily correct. For instance, the detail required from a survey may influence choice of plot size and the minimal area concept makes little reference to ease of sampling or time necessary for sampling (Greig-Smith, 1964).

Braun-Blanquet (1964) considered minimal area to be that area at which the species area curve becomes more-or-less horizontal. This has been a widely used method for determining minimal area, even though it is impossible to objectively determine such an area, as the curve seldom or never becomes truly horizontal and the point of inflection of the curve is dependent on the relative lengths of the abscissa and ordinate (Cain and Castro, 1959).

Generally speaking it is impossible to define minimal area objectively, although various workers have attempted a number of modifications (Goodall, 1952; Hopkins, 1955; Greig-Smith, 1964; Werger, 1972; Kershaw, 1973). Shimwell (1971) concludes that "minimal area will never be more than an approximation, subjectively based on whether the sample area is large enough to represent the characteristic structure and floristics of a plant community".

In the Zurich-Montpellier approach one is not bound to a fixed plot size or plot shape in sampling vegetation (Werger, 1974), because species are rated on a cover-abundance scale with relative values. Plot size should, therefore, be adapted to give a typical description of the stand of vegetation that is represented by the plot, and that care must be taken to ensure that the vegetation in the plot represents an example of one community type only.

For the purposes of this study $100m^2$ square or rectangular plots were used, based on successful studies in the Cape Peninsula forests (Campbell and Moll, 1977; McKenzie, Moll and Campbell, 1977). This plot size was also found to be suitable after using the method of Campbell and Moll, (1976). They determined that plot size depends on such factors as plant size, floristic richness, pattern and cover. A more practical expression of this is the height of the tallest stratum, assuming that the number of species is a function of diversity. Thus height was plotted against species numbers. The areas which yielded 78% diversity were calculated and these areas were plotted on the height versus species graph. This showed a general trend of increasing plot size with an increase in number of species. In this survey 10 x 10m or 5 x 20m plots were employed depending largely on topographical features. The latter was used largely along stream banks and on strong concave slopes.

5.2.4 Structure

Sampling within a stand should be such that each plot adequately represents the structure of the surrounding vegetation (Werger, 1974). In this study vertical and horizontal structure were extremely important with regard to choice of sample site.

The stratification was often complex, with the canopy height ranging from eight metres in short dry forest to some 35m in tall wet forest. In addition to this, sub-canopy trees could be present or absent, and understorey and field layers varied depending on such factors as height and cover of the canopy and sub-canopy strata, the soil depth and type, and the moisture status of the forest stand. The various strata were thus sometimes easily distinguished, while at other times they were hardly recognizable as separate strata. In the true Zurich-Montpellier tradition these strata are considered to be in mutual ecological interaction and cannot be taken as separate and independent ecological units (Braun-Blanquet, 1964; Westhoff, 1967). For the purposes of this study, however, four strata classes were decided upon, these being the canopy, sub-canopy, understorey and field layers. Cover abundance ratings for each species in each of the strata were noted as well as a total rating for the species in all the strata. This greatly facilitates the description and classification as it presents notes on the stratification of individual species and thus facilitates an appreciation of such factors as regeneration and mortality.

Horizontal structure was also of importance in the survey. Many trees are capable of coppice growth, especially where the trees have suffered damage in the past. This was particularly noticeable for Platylophus trifoliatus where the trees had been cut in the past. Consequently careful consideration had to be given the placing of plots in view of the complex structural characteristics.

5.2.5 Floristic Lists

According to the theoretical Braun-Blanquet approach (Shimwell, 1971; Werger, 1974), complete lists of all species occurring in the plot should be drawn up. These should include not only all the vascular plants, but all the mosses, hepatics, lichens, fungi and algae. The requirement of complete species lists cannot be easily met when some geophytes and annuals might not be visible at a particular time. In South Africa most phytosociological surveys have included only perennially identifiable vascular plants (cf. Werger, Kruger and Taylor, 1972; Werger, 1973 a and b; Coetzee, 1974, 1975; Campbell and Moll, 1977; McKenzie, Moll and Campbell, 1977).

In the present study all woody species, ferns and easily recognizable shrubs, herbs and grasses were recorded. The fact that lichens, fungi, mosses and algae were not recorded is not considered a major drawback in this study as the ferns and trees form the more important structural and floristic characteristics.

5.2.6 Cover - Abundance and Sociability

The relative importance of each species in a quadrat was assessed on the well-known cover-abundance scale used by the Zurich-Montpellier school. Cover and abundance were estimated visually in the field and although the scale is subjective, all estimates were made by the author thus obviating any chance of inconsistency which may have occurred if various workers were involved. The following cover-abundance scale as outlined by Werger (1974) was used :

+ Present but not abundant and with a small cover value (less than one per cent of the quadrat area)
1 Numerous but covering less than one per cent of the quadrat area, or not so abundant but covering between one and five per cent of the quadrat area
2 Very numerous and covering less than five per cent of the quadrat area, or covering between five and 25 per cent of the area independent of abundance
3 Covering between 25 and 50 per cent of the quadrat area independent of abundance
4 Covering between 50 and 75 per cent of the quadrat area independent of abundance
5 Covering between 75 and 100 per cent of the quadrat area independent of abundance.

An r, which is included in most surveys and refers to a species with negligible cover was excluded from this survey. However, a plus in brackets, (+), was used for species occurring outside the quadrat and within five metres of the perimeter.

Sociability was not considered in this survey as most of the species were woody and single stemmed. Notes were included on coppicing, however.

5.2.7 Number of Quadrats

There is no theoretical basis on which an exact number of quadrats needed to survey an area adequately can be assessed (Shimwell, 1971; Werger, 1974; Mueller-Dombois and Ellenberg, 1974). The number depends entirely on the scale and purpose of the survey and the degree of precision required. Statisticians agree that a higher sampling intensity reduces the variance in the data more effectively than improved sampling procedure (Goodall, 1970). The number of quadrats should reflect the total variety of the vegetation under consideration. In the present study the number of quadrats in any particular forest site was decided subjectively. In some of the larger forest sites (e.g. Grootvadersbos) it is acknowledged that a greater sampling intensity would probably have shown a more detailed classification of that particular site. However, the time available and the object of this study made this impossible.

5.2.8 Habitat Characteristics

At each quadrat site habitat characteristics were noted. These were mainly of a descriptive nature; little attempt being made to collect detailed habitat data.

At each site the approximate altitude was taken using 1:50 000 Trigonometrical Survey Maps (Trigonometrical Survey Office, 1962). Altitude was an important habitat characteristic because of the significant part played by the mountains in the distribution of forest sites.

The amount of exposure was another habitat characteristic noted at each sample site. This included such notes as exposition to wind, protection from fire (e.g. firebreaks, rock-screes), proximity to running water, protection by cliff faces etc. These notes were purely of a descriptive nature emphasising the position of the quadrat and its surroundings.

The angle of slope and slope direction were measured at each quadrat, the angle of slope being determined by an abney level and the direction of slope with a compass. The slope angle was divided into six subjectively chosen classes as follows :

level	(0 - 3°)
gentle	(3 - 8,5°)
moderate	(8,5 - 16,5°)
steep	(16,5 - 26,5°)
very steep	(26,5 - 45°)
very very steep	(greater than 45°)

Site drainage was noted at each site; this being determined subjectively on the following criteria :

dry
temporarily moist
seasonally moist
seasonally wet
permanently moist
permanently wet

Geology sometimes became a difficult habitat characteristic to note. The underlying geological substrate at some sites were masked by alluvial and colluvial actions. Consequently it was possible to find a considerable amount of mixing of different geological substrates which made the determination of the main substrate difficult.

Rock size and cover were determined at each quadrat site; the cover being estimated using the Braun-Blanquet cover-abundance scale and the size of the rocks recorded using the following diameter scale :

2,5 cms, 15 cms, 60 cms, 2,2m and bedrock

Soil was difficult to collect from some areas, the terrain being very steep and rocky. Soil was collected from five different points in the quadrat from a depth of 25cm. The soils were classified on texture in the field (Loxton, 1962) and samples were brought back to the laboratory where mechanical analysis was attempted. Samples were first air dried, crushed and passed through a 2,0mm sieve to get rid of stones and roots. One kilogram samples were then passed through a series of four sieves, ranging in mesh diameter from 1,5mm to 0,074mm. This proved ineffective in most instances as the small particles clogged the smaller sieves (less than 0,25mm) and thus accurate weighings proved impossible. Even after firing the samples at 600°C for a couple of hours failed to effectively separate out the different particle sizes accurately and effectively. Russel (1973) remarks on the ineffectiveness of sieves below 0,2mm mesh sizes and this would affect the clay content of samples, clay being classed as being less than 0,002mm in particle diameter. Considering the common occurrence of clay soils in the study area it was decided to adhere to the subjective field classification.

Relative amounts of litter and humus were estimated at each quadrat site using the Braun-Blanquet scale as a relative measurement of the amount of each present.

Biotic activity was noted at each quadrat site and included such notes as activity of earthworms, browsing by bushbuck, presence of baboons and signs of cutting and fires. A list of birds recorded in the various forest complexes is given in Appendix 3. Alien vegetation on or near the stand was also noted as this is often indicative of past disturbance.

5.2.9 Relevé

A completed list of species and their relative importance, and the other important characteristics pertaining to vegetation as mentioned above are termed a relevé. In total 103 relevés were made for the purposes of this study.

5.3 DATA SYNTHESIS

Numerous methods have been published describing numerical aids to phytosociological studies (Ceska and Roemer, 1971; Campbell and Moll, 1976; Ceska and Rœmer, 1976) but in this study the Braun-Blanquet table method (Westhoff and van der Maarel, 1973; Werger, 1974; Mueller-Dombois and

Ellenberg, 1974) was used to construct the final phytosociological table. Although this method is subjective, Werger (1974) mentions that results are often similar to those obtained by numerical methods. Coetzee and Werger (1973) and Coetzee (1974) in fact argued that the table method was superior to the numerical methods they tested. Campbell and Moll (1976) pointed out that the numerical methods used by these workers and others had undesirable properties, stating that the efficiency of the method often depended on the nature of the raw data. However, even if possessing undesirable properties, numerical methods are useful especially when very large numbers of relevés and species are involved. It is necessary however for any phytosociologist to become familiar with the method; to understand the intricacies involved by firstly using the table method. The process involved from the "raw table" to the final phytosociological table are well documented in previous works and are not discussed here (Westhoff and van der Maarel, 1973; Werger, 1974; Mueller-Dombois and Ellenberg, 1974).

The plant communities are named after exclusive (treu), selective (fest) and preferential (hold) species. The forest "community" is termed an association whose definition is a plant community that has a definite floristic composition, a uniform physiognomy and is bound to uniform habitat conditions (Werger, 1974). The first two parameters of this definition are generally true for the study region, but the habitat usually confined to kloofs and screes may vary through the study region. The forest association itself was sub-divided into sub-associations and variations.

It is common practice to place the species occurring within a nodum in order of presence, but this has not always been followed in the final phytosociological table (Table 8) mainly because some species are confined to certain forest complexes and do not stretch throughout the noda. For similar reasons the order of relevés within a noda have by and large been grouped into the forest complexes in which they occur. This was necessary because a number of the forests studied had certain characteristics, either floristic, structural or environmental, which were unique.

All species recorded are retained in Table 8 for ease of reference, though as a general rule workers usually place rare species (those occurring in only a few releves) in an appendix.

CHAPTER VI

DESCRIPTION OF THE FOREST COMMUNITIES

Rapanea melanophloeos - Hartogia schinoides - Podocarpus latifolius Forest Association.

This community includes all the forest throughout the study region. Differential species include R. melanophloeos, H. schinoides, P. latifolius, Maytenus accuminata, Kiggelaria africana and Knowltonia capensis.

The smaller forests occur mainly on well protected sites where protection from fire is adequate, and water availability reasonably high. The larger forests occur at the base of the Langeberg and Riviersonderend mountain ranges on relatively deep (greater than 1m) clay soils. Forests are also found on granite and sandstone derived soils which in places can be less than 0,5m deep.

The amount of litter and humus associated with these soils varies from over 80% in tall wet forest to less than 10% in short dry forest. The south-facing slopes on which these forests mainly occur vary from gentle to very steep.

Common canopy species are R. melanophloeos, P. latifolius and K. africana with various other species being prominent depending on the moisture status of the forest site and its particular position on the east-west gradient. The canopy height varies from 8 - 12m in short dry forest to some 35m in tall wet forest. The canopy cover is usually over 80% being more open only on streambanks and on screes.

Typical sub-canopy and understorey trees are H. schinoides, M. accuminata and Halleria lucida. The sub-canopy and understorey layers may be present or absent depending on the particular site, and vary in height with the canopy.

The ground layer is generally sparse, except in wet forests where a variety of ferns occur. According to Ellenberg and Mueller-Dombois (1967) this paucity is a feature of broad-leaved forests of winter rainfall areas. The percentage cover of the ground layer increases from west to east, that is with an increase in percentage summer rainfall, but remains poor when compared to the sub-tropical forests along the east coast of South Africa. Usual species encountered apart from ferns are Schoenoxiphium lanceum, K. capensis and various Oxalis spp. Asparagus scandens, a climber is also often present in the ground layer.

This forest association can be divided into a number of smaller units based firstly on moisture availability and secondly on longitude.

6.1 *Cunonia capensis* - *Platylophus trifoliatus* sub-Association

This is the forest of the wet sites, on either deep soils or shallower soils along streambanks (see Photos 6 and 7). The differential species of this sub-association are *P. trifoliatus* and *C. capensis*. This forest has three variations which are distinguished largely on the amount of moisture available.

Although *P. trifoliatus* shows the highest constancy for this sub-Association, *C. capensis* along with the various species which characterize the internal variations is a better indicator species. This is because the geographical distribution of *P. trifoliatus* does not extend across the Cape Flats to the Cape Peninsula forests. The three Variations are distinguished by differential species in one case, the presence of "wet" ferns in the second, the presence of drier species in the third; the latter being divided into two sub-Variations.

6.1.1 *Sparrmania africana - Cunonia capensis - Platylophus trifoliatus* Variation

This forest Variation probably accounts for the best developed forest of the entire study area. The forest occurs on deep, black soils where humus and litter content are very high (over 80%). It occurs essentially on steep slopes where the deep soil has been derived mainly from shales, although some areas (e.g. Boesmansbos) have a sandstone cap probably as a result of colluvial action.

The differential species of this Variation are *Elaphoglossum conforme*, *S. africana* and *Brachylaena nerrifolia*. This nodum, like a number of others on the phytosociological table, is distinguished partly by the fact that the three differential species are mainly restricted to two forest complexes, Boesmansbos and Jonkersberg (see Fig. 6). Boesmansbos is a high altitude forest occurring at some 1500m and has suffered little exploitation, while Jonkersberg at the eastern extreme of the study area forms the start of the well developed forest types of the Knysna district.

This Variation forms very tall forest with the canopy reaching 35m in places. The dominant species in the canopy, which is usually completely closed, are *P. trifoliatus*, *C. capensis* and *Ocotea bullata*. *Ilex mitis*, *Olea capensis* subsp. *macrocarpa* and *Podocarpus latifolius* are also present in the canopy in certain stands. *O. bullata*, which is present in all but one relevé in this Variation has higher cover abundance values here than in any of the other variations.

The sub-canopy is usually some 15m high and has a percentage cover of less than 50%. The dominant species in the sub-canopy are *Pterocelastrus rostratus*, *P. latifolius*,

O. capensis subsp. macrocarpa and I. mitis. Rapanea melanophloeos has its lowest cover abundance values in this Variation and often occurred outside the relevé indicating that it is only rather widely dispersed in this Variation.

Although the understorey stratum is dominated by ferns, the more common trees are Clutia pulchella, Hartogia schinoides and Maytenus accuminata. The two dominant ferns in this stratum are Alsophilla capensis (Forest tree fern) and Todea barbara. In very wet areas A. capensis has the highest cover abundance and dominates the understorey layer. It sometimes grows up to 2m tall and forms a closed canopy with an extremely sparse ground layer. T. barbara grows to about a metre high in places where it is not crowded out by A. capensis. Polystichum ammifolium is usually present in the ground layer while Blechnum punctualatum and B. attenuatum are only locally dominant.

The number of species in the canopy layer is usually low, being between two or three per $100m^2$, and consisting sometimes of only two individuals which comprise the canopy cover of over 80%. The number of species present in the sub-canopy and understorey layers vary from two to eight per relevé, depending on the site, while the ground layer usually contains more than 10 species.

Virgilia oroboides has an interesting performance in this Variation. In one stand at Boesmansbos this species was a tall canopy tree in very well layered forest. The diameter at breast height of some of the individuals was almost 1m and these trees were up to 20m high. This is of interest because *V. oroboides* is generally thought of as a marginal species and does not usually exceed heights of more than 12m.

Hymenophyllum spp. and *Pepperomia retusa* were encountered on moist seepy areas while the occurrence of two water loving species, *Zandetischia aethiopica* and *Blechnum capense* were rare in the ground layer.

6.1.2 *Cunonia capensis - Todea barbara* Variation

This Variation differs only slightly from the previous one. It is less developed and has probably suffered more exploitation, the canopy height being lower (ranging from 7 - 23m) with a reduced canopy cover especially along streams. It generally contains less litter and humus than the previous Variation, indicating it is possibly less moist. It also occurs on both sandstone and shale on steep to moderate slopes which may either have a high presence or total absence of rock cover. This Variation is one of the few communities that can be found throughout the study region where the right combination of habitat factors occur.

The species characterising this Variation are largely the same as for the Sparrmania africana - Cunonia capensis - Platylophus trifoliatus Variation. The main difference is the low cover abundance values for P. trifoliatus the canopy layer being dominated by C. capensis in association with Ilex mitis, Olea capensis subsp. macrocarpa, Podocarpus latifolius or Ocotea bullata. Of the 18 relevés representing this group no less than 14 have cover abundance values of 1 or less for P. trifoliatus, indicating that when present it is not usually a canopy species. Half of the relevés show either an absence of the species or that it only occurs outside the relevé indicating that it has a rather low density in this Variation.

The understorey trees and ground layer species differ little from the previous Variation, but the constancy of T. barbara increases and where Alsophilla capensis has low cover or is absent, T. barbara often forms the dominant ground layer species. The ground layer cover varies considerably from less than 3% to over 80%.

Brabejum stellatifolium is sometimes encountered in this Variation, especially along streams where it grows to about 2m. This species is not a "true" forest species as it usually lines streambanks in areas outside "true" forest.

Blechnum capense, a tall fern, which forms dense clumps in the wet forest of the Knysna region, is also frequently encountered in this Variation but usually has low cover abundance values.

The canopy layer of this Variation can contain up to five species per relevé while the sub-canopy, understorey and ground layers follow much the same pattern as the previous Variation, although the sub-canopy is lower and sometimes difficult to distinguish from the understorey.

6.1.3 Rapanea melanophloeos - Platylophus trifoliatus Variation

This is a drier Variation of the Cunonia capensis - Platylophus trifoliatus sub-Association and two sub-Variations are identifiable. It is differentiated from Variations 6.1.1 and 6.1.2 in not having a dense understorey of ferns and in containing a number of species which are common to the dry forests but usually absent in the Sparrmania africana - Cunonia capensis - Platylophus trifoliatus and Cunonia capensis - Todea barbara Variations. The division into two sub-Variations is based on the virtual absence of three wet forest species in the one. These are Alsophilla capensis, Ocotea bullata and Ilex mitis.

Phytogeographically this Variation occurs throughout the study area, generally on soils that are shallower than those of the wetter Variations and often on sites that have at least 5% of rock cover (the boulders frequently being at least 2,2m in diameter). The amount of litter and humus present is similar to the Cunonia capensis - Todea barbara Variation, but the slope, aspect and geology vary considerably.

The canopy height varies from 6 - 22m with a percentage canopy closure from 40 - 85%. The sub-canopy varies from as low as 8% to as much as 45% and the height varies with the canopy, sometimes being difficult to distinguish as there is a large amount of straddling. The understorey layer in this Variation has considerably less cover than the previous Variations; the highest cover recorded being 40%. This is at least 10% higher than any of the other relevés of this Variation and is mainly due to the presence of Alsophilla capensis. The cover in the ground layer varies from 1 - 30% but is usually about 5%. Up to five species are recorded per relevé in the canopy layer while the sub-canopy layer can have up to eight species per relevé. The number of species in the understorey and ground layer differ remarkably per relevé; one to 11 being the range in the understorey and three to 19 in the ground layer.

R. melanophloeos has a higher cover abundance in this Variation than the previous two and is the main canopy tree, along with *C. capensis*, *Ilex mitis*, *P. trifoliatus* and *Podocarpus latifolius*. *Apodytes dimidiata* and *Olinia ventosa* occur as occasional canopy trees, though they are more common in drier forests.

Common sub-canopy trees are *Olea capensis* subsp. *capensis*, *Hartogia schinoides* and *Maytenus accuminata*. *Pterocelastrus rostratus*, a common sub-canopy species in previous mentioned Variations (6.1.1 and 6.1.2), is less common here and is only present in the understorey.

Cassinopsis ilciflora, *Curtisia dentata*, *Diospyros whyteana* and *Maytenus heterophylla* form the understorey stratum, replacing the ferns of the wetter Variations. These do not occur generally but are scattered through the region (see Table 8). The ground layer is rather sparse with species like *Knowltonia capensis*, *Asparagus scandens*, *Schoenoxiphium lanceum*, *Carex aethiopica*, *Histiopteris incisa*, *Dietes vegeta*, *Asparagus aethiopicus*, *Blechnum australe*, *Cassinopsis ilciflora* and *Carissa bispinosa* occurring. Seedlings of canopy trees are also common.

6.2 *Carissa bispinosa - Canthium ventosum - C. mundianum - Pterocelastrus tricuspidatus* sub-Association

This is the drier forest type in the study area and occurs throughout where conditions are favourable. The species after which this sub-Association is named are neither character nor differential species, but are representative of this sub-Association in general. The distribution of these species in the final phytosociological table (Table 8) appear to be rather inconsistent. This is mainly due to three factors. Firstly, C. bispinosa is a species which only extends as far west as the Riviersonderend forest complex; secondly, P. tricuspidatus is a species much more dominant in the eastern forests of the study area, and, thirdly, there is competition between C. ventosum and C. mundianum for sub-canopy space and other species in the various forests.

The combinations of canopy, sub-canopy and understorey tree species vary considerably throughout this sub-Association and are discussed under the different Variations.

This forest type occurs on any forest soil type, on gentle to steep slopes where the site drainage is usually good though in some cases the site may be seasonally or temporarily wet. The amount of litter may be high, but the humus content of the soil is generally lower than the Cunonia capensis - Platylophus trifoliatus sub-Association. As is the case in most of the forests, aspect is not significant.

6.2.1 Gonioma kamassi - Nuxia floribunda Variation

This is the drier forest Variation of the most easterly occurring forest in the study area. It only occurs occasionally on seasonally moist sites on either sandstone or shale derived soils. The slope varies from gentle to steep, and rocks are usually absent.

The characteristic species of this variation are G. kamassi, N. floribunda, Trichocladus crinitus, Cassine papillosa, Trimeria grandifolia and Lachnostylis hirta. Although there are a number of herbaceous plants and ferns peculiar to this Variation, they are not considered especially characteristic because they were recorded infrequently.

Four of the characteristic species mentioned above are restricted to the Jonkersberg complex (see Fig. 6 and Table 7) while the other two, N. floribunda and L. hirta occur further west, but are rare.

The common canopy tree species include Podocarpus latifolius Rapanea melanophloeos, Olea capensis subsp. macrocarpa, Olinia ventosa and N. floribunda. The first four are the more common trees in taller forest (15 - 20m) while N. floribunda, G. kamassi, Canthium obovatum and C. papillosa are more important canopy species in shorter forest (12 - 13m tall). Canopy cover varies from 30% to over 70%, depending on local conditions, the lower percentage cover usually being associated with disturbed areas or areas where tree falls have opened the canopy. Ocotea bullata may be present in the canopy layer in wetter stands of this Variation.

The sub-canopy layer which usually reaches heights between 8 - 10m usually has additional tree species such as Hartogia schinoides, Burchellia bubalina, T. grandifolia, Rothmannia capensis, L. hirta, Kiggelaria africana and Pterocelastrus tricuspidatus.

The principal understorey species are T. crinitus, Rhamnus prinoides, R. capensis, B. bubalina, L. hirta, Halleria lucida, Diospyros whyteana, Cassinopsis ilciflora and P. latifolius. The understorey of this Variation is the most dense in terms of number of individuals present, of all the forest types, though the percentage cover is usually less than the wet forests of the Cunonia capensis - Platylophus trifoliatus sub-Association. Up to 35 individuals of P. latifolius and T. crinitus can be present in one relevé. Considering this high density, the percentage cover (usually less than 40%) might be expected to be higher. However, there is a lot of straddling and clumping.

Maytenus accuminata, a common tree in sub-canopy and understorey layers of most forests, is often absent from this Variation and when present usually has a low cover.

The ground layer normally has less than 10% cover, but it may be as high as 35% in places. The common species of this layer are Schoenoxiphium lanceum, Ruhmora adiantiformis, Scutia myrtina, Carissa bispinosa, Dietes sp., Oxalis sp., Knowltonia capensis, Asparagus scandens and Carex aethiopicus, while in wetter areas Polystichum ammifolium and Blechnum tabulare may be found.

6.2.2 Buddleja saligna - Scolopia mundii Variation

This Variation differs principally from the previous one in not having the six characteristic species of that Variation, the presence of B. saligna, and a high constancy for S. mundii. These two species are common in the dry and very dry scrub forests of the Southern Cape, but are uncommon in tall dry forest (Von Breitenbach, 1974) and are absent from any of the wetter types. Campbell and Moll (1977) included a forest type they called the Scutia myrtina - Scolopia mundii sub-association in their survey of the forests of Table Mountain. This sub-association was the most extensive on the Mountain and included all the trees of the forests. In this survey S. mundii and S. myrtina are restricted to the drier forest complexes of the eastern section of the study area.

The important canopy tree species in this rather short forest (usually less than 15m tall) are Olinia ventosa, Podocarpus latifolius, Rapanea melanophloeos, Hartogia schinoides, Apodytes dimidiata, Olea capensis subsp. macrocarpa, Olea capensis subsp. capensis, Pterocelastrus restratus and Kiggelaria africana. It is interesting to note that in this shorter forest H. schinoides and P. rostratus are canopy components while in the previously described Variations, where the forest was taller, these two species were usually confined to the sub-canopy and understorey layers. This shorter forest allows more individuals to contribute to the canopy layer and up to 12 individuals were counted per relevé, with many combinations of species.

The sub-canopy layer, commonly about 11m tall with up to 15 individuals per relevé, principally consists of Canthium ventosum, R. melanophloeos, H. schinoides, P. rostratus, Maytenus accuminata, Rothmannia capensis K. africana, A. dimidiata, B. saligna and S. mundii.

The understorey which has a much poorer cover (less than 20% being normal) than the Gonioma kamassi - Nuxia floribunda Variation, is not dominated by a few species as was the case in the last mentioned Variation, but contains up to 11 species per relevé. The principal trees are O. capensis (both subspecies), H. schinoides, Maytenus heterophylla and B. saligna, while Cassinopsis ilciflora may reach understorey height in places. When Curtisia dentata is found in this Variation it is usually confined to this layer.

The prominent species in the ground layer are Carissa bispinosa, Cassinopsis ilciflora, Dietes sp. Scutia myrtina, Knowltonia capensis, Asparagus scandens and Oxalis sp.

6.2.3 Rothmannia capensis - Olinia ventosa - Canthium ventosum - C. mundianum Variation

This Variation is similar to the previous two in that it contains the four species which are largely exclusive to these three Variations, namely, R. capensis, Burchellia bubalina, Maytenus heterophylla and Ruhmore adiantiforme. However, it differs in having the species characteristic of these Variations (6.2.1 and 6.2.2) being virtually absent. Consequently the species combinations in the various layers are different, especially in the sub-canopy and understorey layers (see Photo 8).

The two dominant species in the canopy are Rapanea melanophloeos and Olinia ventosa. Other canopy species are Apodytes dimidiata, Olea capensis subsp. macrocarpa and Kiggelaria africana, with Virgilia oroboides and Ocotea bullata occurring only rarely. The canopy height is some 15m with a canopy cover of some 50% throughout.

The sub-canopy varies in cover between 20 - 50%, common species being R. capensis, Pterocelastrus rostratus, Hartogia schinoides, Halleria lucida and Canthium mundianum and *C. ventosum*.

The understorey layer which generally has no more than 20% cover usually contains various species of the canopy and sub-canopy layers with no species being dominant.

The cover of the ground layer may be as high as 80% locally, where *Schoenoxiphium lanceum* is dominant. Common species besides this are *Ruhmora adiantiformis*, *Blechnum australe*, *Dietes* sp. and *Carissa bispinosa*.

6.2.4 *Cassine peragua - Linociera foveolata - Grewia occidentalis* Variation

This is the driest forest of the study area (see Photo 9) and is dominated by species known to be characteristic of dry forests, namely *C. peragua* and *G. occidentalis* (Phillips, 1931; Taylor, 1955; von Breitenbach, 1974; Campbell and Moll, 1977). *L. foveolata* although common in very dry forest is also found in medium moist forests of the Southern Cape (von Breitenbach, 1974).

This forest Variation is found throughout the study region except in forested areas that are small and restricted to wetter kloofs. It occurs over a wide range of environmental conditions, often on gentle to moderate east facing slopes. Very little litter is present (less than 15% cover) and the humus content of the topsoil is low. Rock cover is usually low, being high only where large boulders occur.

The species distinguishing this Variation are C. peragua, which has high cover abundance values and over 85% constancy in this Variation, L. foveolata, G. occidentalis and a herbaceous Chlorophytum sp.

This variation has a low canopy which never being higher than 16m, with a canopy cover usually greater than 60%. Sub-canopy, understorey and ground layer cover is low; with the sub-canopy cover occasionally reaching 40% and the cover of the lower two strata usually less than 10%.

Common canopy tree species are C. peragua, Podocarpus latifolius, Rapanea melanophloeos, Hartogia schinoides, Pterocelastrus tricuspidatus, Olea capensis subsp. capensis, Olea capensis subsp. macrocarpa and Diospyros whyteana. The three most common species are C. peragua, Podocarpus latifolius and Rapanea melanophloeos.

The sub-canopy species include all the common canopy species plus Canthium ventosum, C. mundianum, Apodytes dimidiata, Kiggelaria africana and L. foveolata. The most common species are O. capensis subsp. capensis and C. ventosum.

The most important understorey species in terms of dominance are G. occidentalis, Halleria lucida, D. whyteana, C. ventosum, C. mundianum and L. foveolata.

The ground layer, although poor in cover, often has a large number of species present; up to 17 per relevé having been recorded. A small shrub form of G. occidentalis is common in the ground layer, while the Chlorophytum sp. is very prominent in this Variation. Other typical species of the ground layer are Scutia myrtina, Carissa bispinosa, Stipa dregeana, Oplismenus hirtellus, Schoenoxiphium lanceum, Asparagus scandens, A. plumosus, Blechnum australe and a Dietes sp.

Olinia ventosa is not as common in this variation as the previous mentioned ones of this sub-Association (6.2). This is unexpected as von Breitenbach (1974) terms it a frequent tree of the dry forest types of the Southern Cape but absent from the moist forest types. The possibility arises that in this Variation C. peragua, P. latifolius and R. melanophloeos are too competitive for it to be a commonly occurring species.

6.2.5 Cassinopsis ilciflora - Olea capensis subsp. capensis - Carissa bispinosa Variation

This Variation differs from the aforementioned Variations of sub-Association 6.2.1 by the lack of species which are considered to be restricted to dry forest types, and by the higher cover-abundance values of species common throughout the sub-Association (see Photo 10).

The common canopy species are Olinia ventosa, Apodytes dimidiata, Olea capensis subsp. capensis, Podocarpus latifolius and Rapanea melanophloeos. Olea capensis subsp. macrocarpa is found occasionally in the canopy, while in wetter areas Platylophus trifoliatus, Cunonia capensis and Ilex mitis may be found. From the list of species mentioned above it is apparent that this Variation is found in dry to seasonally wet areas. The canopy varies between 13 - 17m tall with a total cover varying from 40 - 85%.

The sub-canopy is 7 - 10m tall with a percentage cover ranging from 10 - 70%. The more important sub-canopy species are Apodytes dimidiata, Hartogia schinoides and Maytenus accuminata; the latter two, together with O. capensis subsp. capensis, Kiggelaria africana and Clutia pulchella (wetter areas) are common in the understorey. Cassinopsis ilciflora and Carissa bispinosa occasionally grow over 1m tall while Todea barbara is found in wetter areas. Canthium ventosum and C. mundianum are also found in the understorey but usually have a cover value of less than 1%.

C. bispinosa, C. ilciflora, Asparagus plumosus, A. scandens, Schoenoxiphium lanceum, Knowltonia capensis, Oxalis sp. and Dietes sp. dominate the ground layer which is often covered by up to 50% rock cover.

The wetter stands of this Variation (relevés 95 and 96) are particularly interesting as they are different to the wetter stands of sub-Association 6.1. These two relevés come from Olifantsbos which is a forest belonging to the Riviersonderend complex. It is entirely surrounded by steep cliffs and is situated on very shallow colluvial sandstone soils. It gives the impression of being dry until the species are examined. There is probably a higher moisture availability here from water running down the cliff faces which would account for the greater preponderance of wetter species.

6.3 Maytenus accuminata - Olea capensis subsp. macrocarpa sub-Association

This sub-Association is rather odd as it contains only a few species which are characteristic of the previous two sub-Associations. Maytenus accuminata and Olea capensis subsp. macrocarpa are the only two species with cover-abundance values greater than 1, which are present in all six of the relevés of this sub-Association.

The occurrence of stands of forest with a species composition such as represented by this sub-Association indicates the variety of the forests in the study area. Communities can only be easily recognised when the broad environmental factors are considered, (e.g. moisture content, geographical position) as has been indicated in the description of the two previous sub-Associations (6.1 and 6.2).

This community is found throughout the study area, the releves being representative of the Grootvadersbos, Hottentots Holland and Cape Peninsula forest complexes. The canopy, sub-canopy, understorey and ground layer composition is indeed complex and it would be difficult to attempt to discuss this variation in any detail. The various species and their importance values are given in Table 8 and only the most important characteristics are discussed below.

The high cover value for Maurocenia frangularia in relevé 103 is worth comment. This species was only present in this one relevé in the study area and had a high cover-abundance value. Another important feature was the high percentage of rock cover found in this relevé. It is of particular interest in view of the findings of Campbell and Moll (1977). In their study of the forests of Table Mountain they recognised a Maurocenia fragularia - Olea africana sub-association which was characterised by the presence of high rock cover (100%) and the virtual dominance of M. frangularia.

Important species of this sub-Association other than the general species of the association are _Olinia ventosa_, _Olea capensis_ subsp. _capensis_ in the canopy and _Linociera foveolata_ and _Maytenus heterophylla_ in the sub-canopy and understorey layers respectively.

CHAPTER VII

ORDINATION

INTRODUCTION

Gleason (1926) and Ramensky (in Whittaker, 1960) first proposed the individualistic hypothesis of vegetation composition, on which the ordination technique was founded. The hypothesis states that no two communities are strictly identical in floristic composition. Instead, communities exhibit continuous variation in their detailed floristic composition and cannot be readily delimited as clear-cut entities. No discontinuities occur, except where there are discontinuities in the physical environment.

Ordination itself has been defined by Goodall (1954) as "an arrangement of units in a uni or multidimensional order". The emphasis is on the arrangement of sample units by individual values rather than by group values. In contrast, an arrangement by group values would result in classification. Ordination has sometimes been considered an alternative to classification (Mueller-Dombois and Ellenberg, 1974). However, an ordination of stands will expose the relative continuity or discontinuity between them and the two processes (classification and ordination) are separate but intimately linked which should complement each other.

Curtis and McIntosch (1951) arranged species of the prairie forest of Wisconsin in a one dimensional array, representing the gradient from pioneer species to climax species. This study was one of the first botanical studies to investigate ecological interactions using the ordination technique. Because all the stands or species placed together on one axis may be dissimilar, yet may occur close together on one axis, Whittaker (1956 and 1960) and Bray and Curtis (1957) developed multidimensional ordinations as an improvement. This has the advantage that clustering tendencies of stands can be shown geometrically, though the recognition of groups still remains a matter of personal judgement.

The first step in multidimensional stand ordination is the calculation of a similarity index for each stand pair of the sample series. The most widely used similarity index (community coefficient) is that of Bray and Curtis (1957) which has the formula :

$$PS = \frac{2w}{(a+b)}$$

where $\underline{a}$ is the sum of the quantitative values in one stand

$\underline{b}$ is the similar sum for values in the second stand

and $\underline{w}$ is the sum of the lesser value for only those species which are in common between the two stands.

Gauch and Whittaker (1972) suggested that the Bray-Curtis ordination, using the complemented coefficient of community was the best general method, although Kessel and Whittaker (1976), after comparing a number of distance measures (Euclidean distance, complement of percentage similarity and the coefficient of community), suggested that the coefficient of community (CD) is only better than the complement of percentage similarity (PD) under certain conditions. The Euclidean distance (ED) gave the most distortion of the three distance measures used. For the purposes of this study, the distance measure used was the coefficient of community (CD).

The computer program used was the Cornell Ecology Program 4 (Gauch, 1976) with an internal association (IA) of 100%. Beals (1960) subtracted similarities from an "internal association" of 85% to convert the typical similarity values to distance values. The 85% represented the typical similarity value between replicate samples. "Differences of a few percent in the IA value used usually have only minor effects on the results of an ordination; in fact, similar ordinations may be produced using 100% in place of an IA estimate" (Bannister, 1968 in Gauch, 1976).

End-point selection was chosen subjectively in this program, experience having shown "that letting the smallest similarity index define the end-points can fail entirely because there are several zeros; it can be meaningless because other candidates are near enough to the smallest index to be statistically indistinguishable; or it can lead to a choice without any obvious ecological meaning or interpretability" (Gauch, 1976).

The complementing coefficient of community (CC) gives the measure (CD) using the equation :

$$CD = IA - CC \quad \text{(IA being 100 for this survey)}$$

Two and three dimensional ordinations have been drawn from the above program, the third dimension being calculated from using two subjectively chosen end-points within the two dimensional ordination. The end-points used in the two dimensional ordination after using a number of combinations were stands 9 and 59, and 47 and 100, while stands 45 and 76 respectively were used for the third dimension.

With little appropriate environmental data available the ordinations have been compared by plotting the distribution of species on the ordination diagrams. It is evident from the species plotted that the species complexes follow very closely the communities recognised in Table 8.

The two ordinations complement the use of the Braun-Blanquet technique, the three dimensional ordinations being better than the two dimensional model.

Quantitative values used for the calculation were as follows (Coetzee and Werger, 1973) :

B.B. value	Calculation value
(+) r	1
+	5
1	10
2	20
3	30
4	40
5	50

CHAPTER VIII

ORDINATION : RESULTS AND DISCUSSION

8.1 PRIMARY ORDINATION

8.2 DELIMITATION OF COMMUNITIES

Five groups of floristically related stands are grouped and named after species which are indicative of these groups. The groups which have been delimited within the ordination (Fig. 7) are termed "communities" to distinguish them from the units recognised in the phytosociological survey. Isolines have been employed to show the distribution of the communities and the releves within each community type recognised. The delimination was done subjectively taking cogniscance of the position of the releves in the field and within the ordination, and species distributions and cover-abundance ratings within the ordination. No attempt has been made to ordinate species within various strata or plot densities on the diagrams. The relative importance of the species in various strata are described in the text while the cover-abundance ratings give some idea of density.

The five communities which are shown in Fig. 7 are :

(A) *Cunonia capensis* - *Todea barbara* community

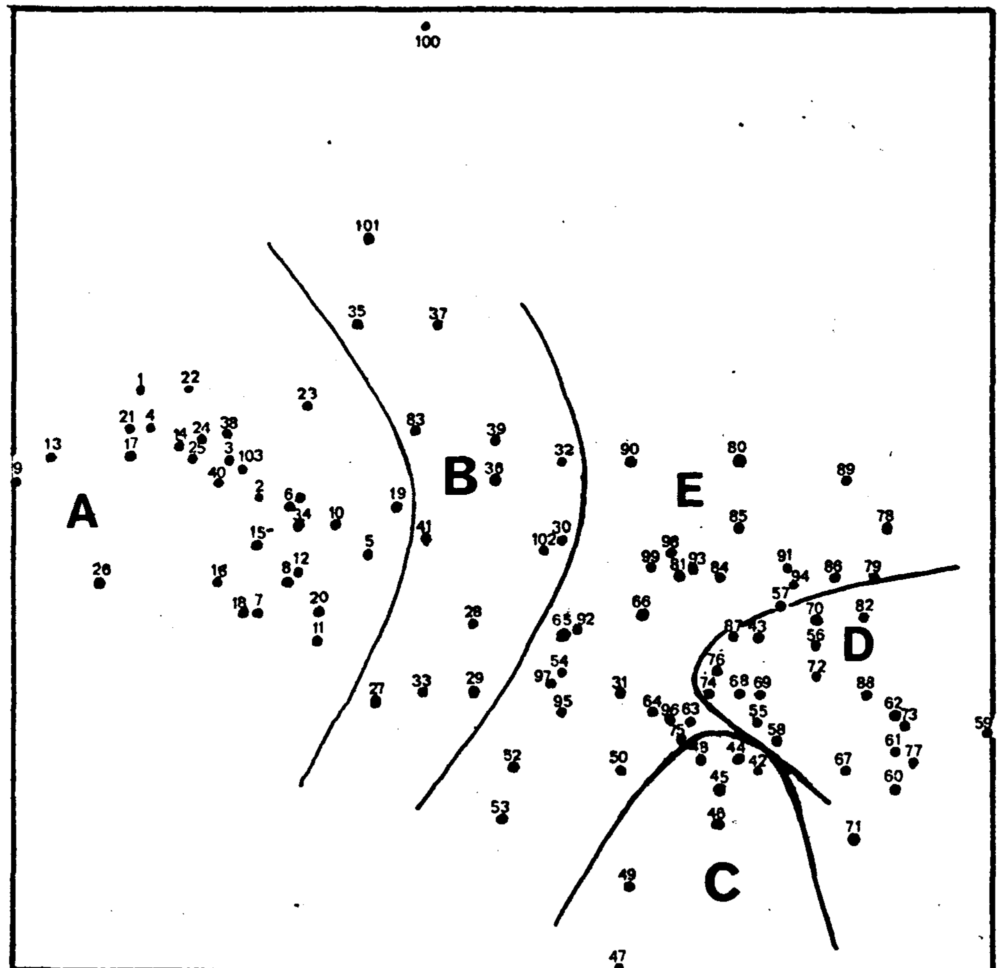


Fig 7: Distribution of the relevés within the primary ordination. The isolines separate the five communities, A, B, C, D and E referred to in the text.

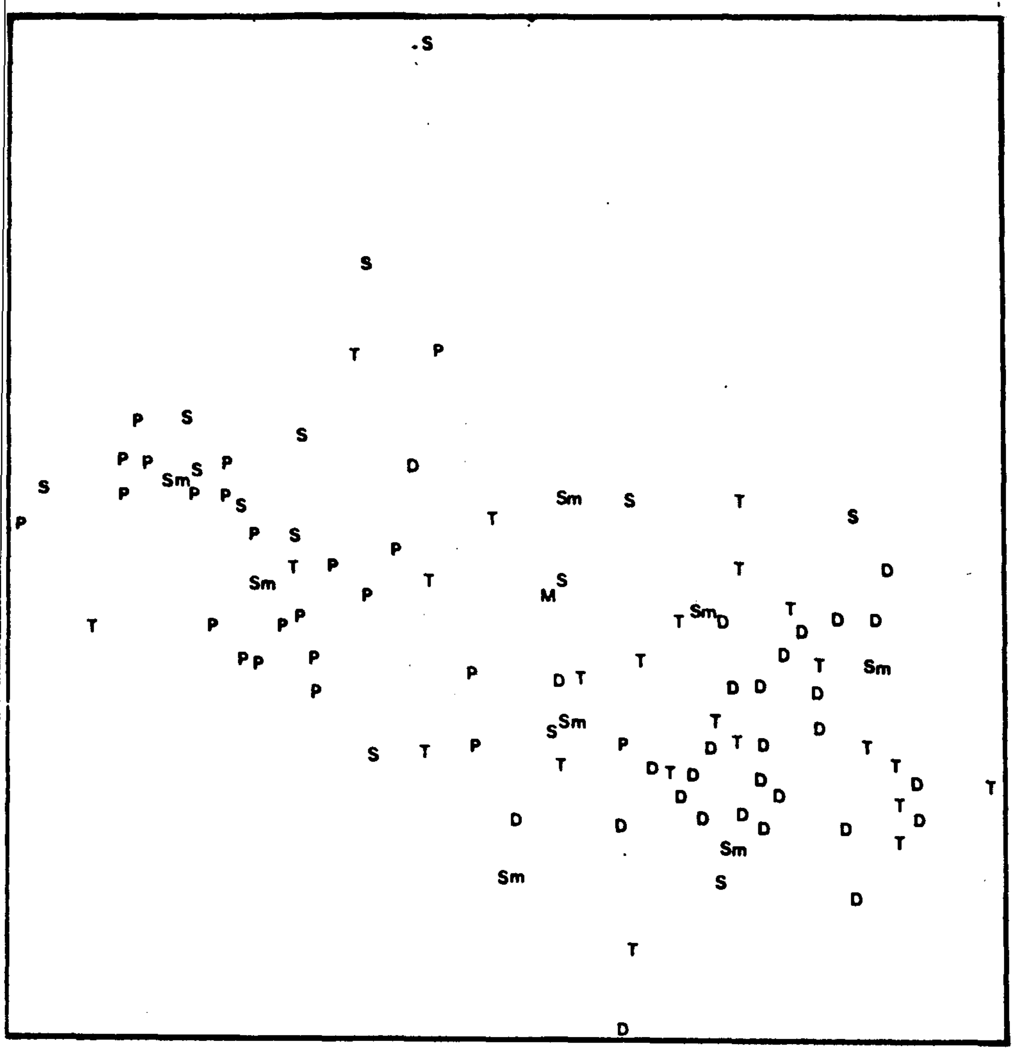


Fig 8: Primary ordination showing the distribution of moisture status (P = permanently wet, Sm = seasonally moist, S = seasonally wet, M = permanently moist, T = temporarily moist, D = dry)

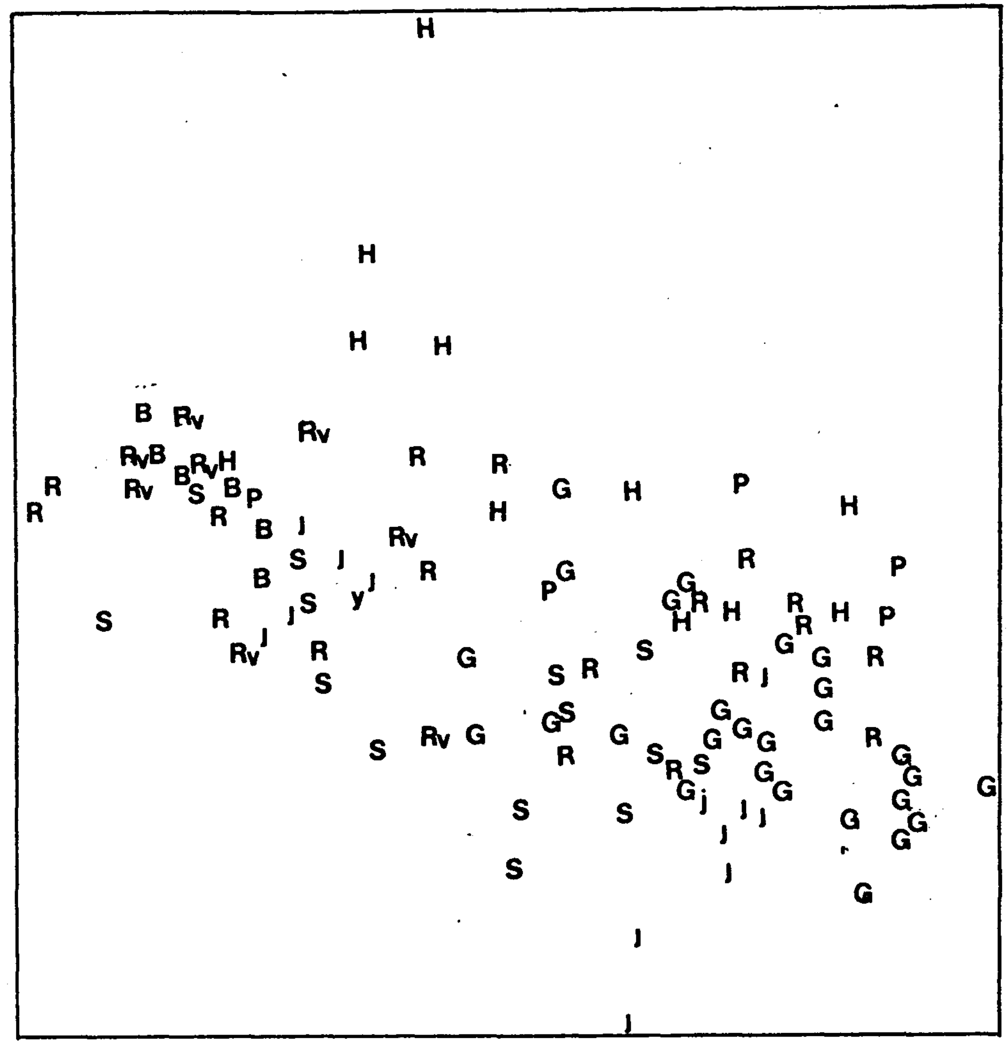


Fig 9: Primary ordination showing the distribution of the forest complexes (J = Jonkersberg, Rv = Riversdale, G = Grootvadersbos, B = Boesmansbos, S = Swellendam, R = Riviersonderend, H = Hottentots Holland, P = Cape Peninsula)

(B) Cunonia capensis - Platylophus trifoliatus community

(C) Gonioma kamassi - Nuxia floribunda community

(D) Cassine peragua community

(E) Rothmanniacapensis - Cassinopsis ilciflora community

Selected species with their respective cover-abundance values were plotted on the ordination diagrams while species showing similar trends to these are mentioned in the text. The two environmental parameters which are important in the distribution of the communities are site drainage and the locality which are shown in Figs. 8 and 9.

8.3 COMMUNITY CHARACTERISTICS

8.3.1 (A) Cunonia capensis - Todea barbara community

This is the community of the wet sites and occurs throughout the study region. Typical species which are representative of this community and largely restricted to it are Cunonia capensis, Todea barbara, Alsophilla capensis, Blechnum capense, B. attenuatum and B. punctualatum. All these species are represented in Figs. 11, 12, 15, 10, 14 and 13. Except for C. capensis, all the other species mentioned above are ferns, all of them virtually restricted to this community. These ferns are thus typical of wet forest stands and are found only sporadically in the drier forest types, which are on the right hand side of the

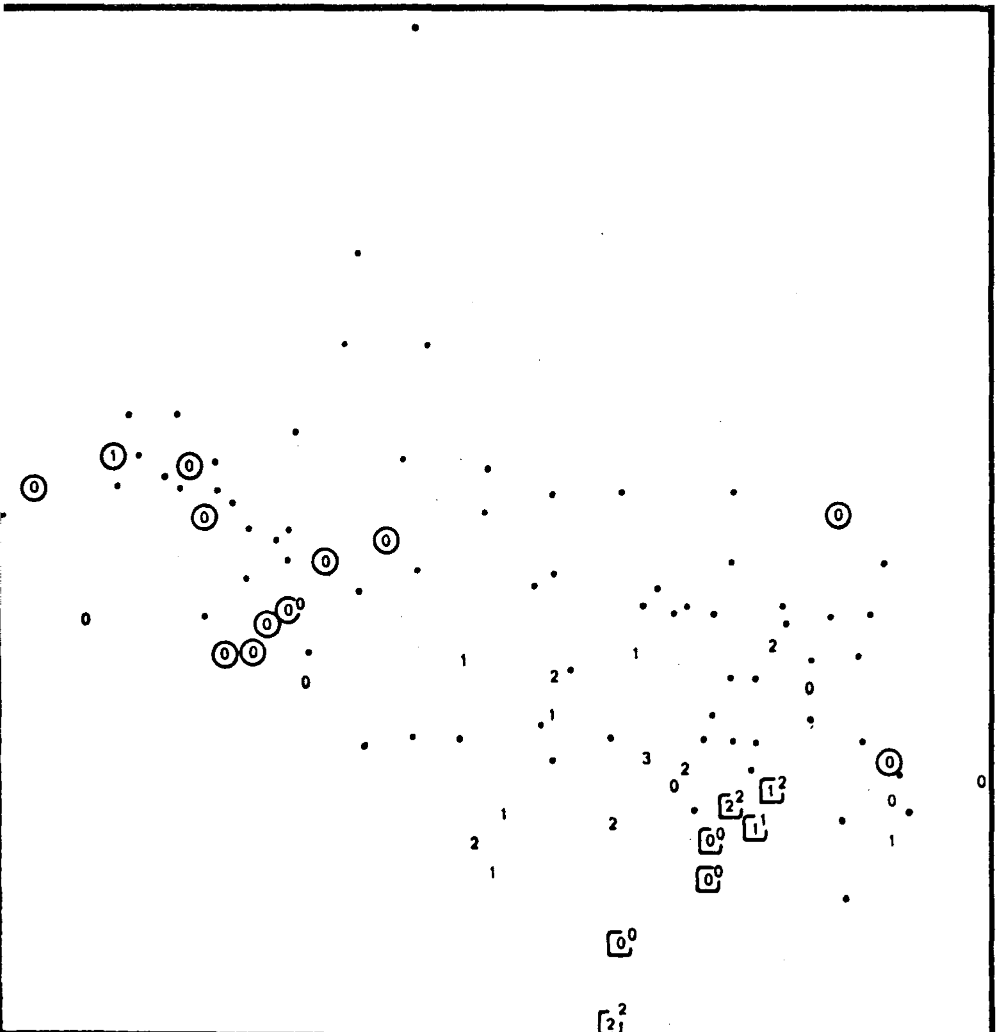


Fig 10: Distribution and cover-abundance values within ordination of:

1 Rothmannia capensis
[1] Nuxia floribunda
(1) Blechnum capense
• All above species absent

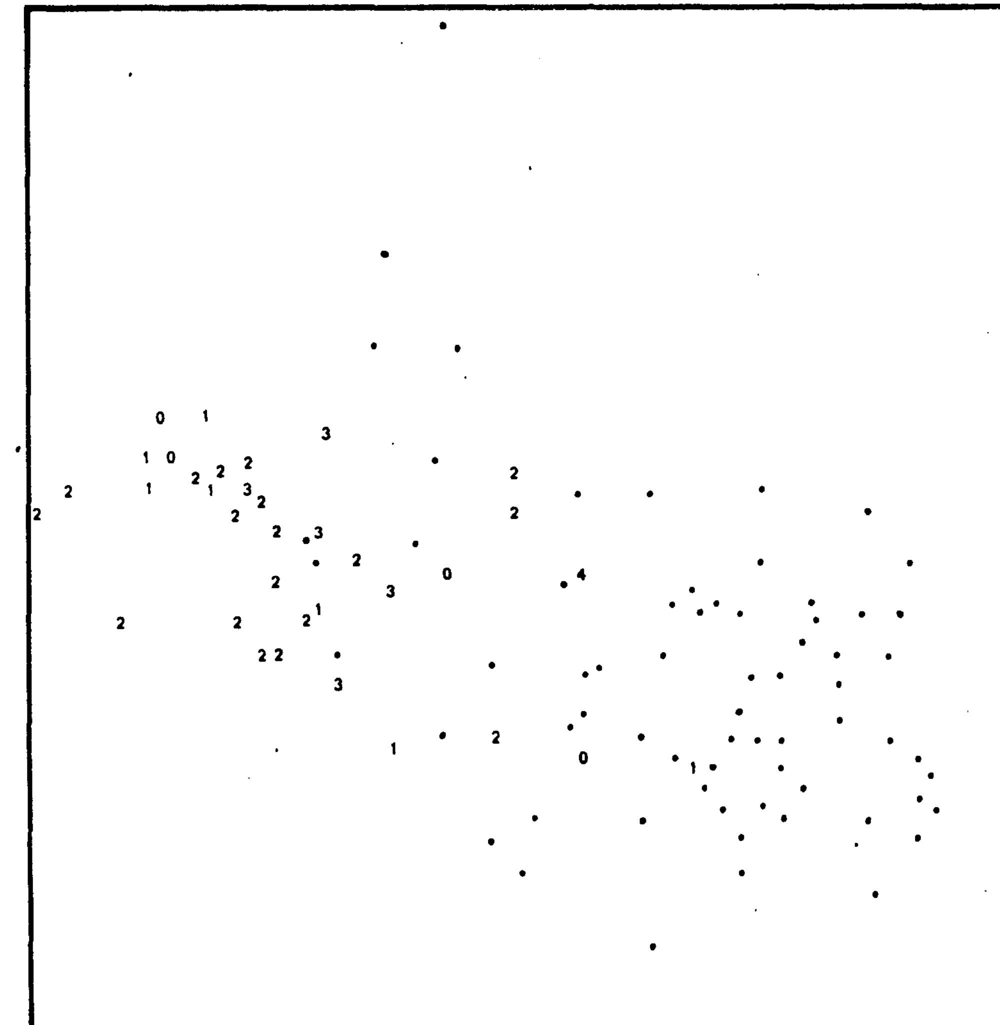


Fig 11: Distribution and cover-abundance values within ordination of Cunonia capensis

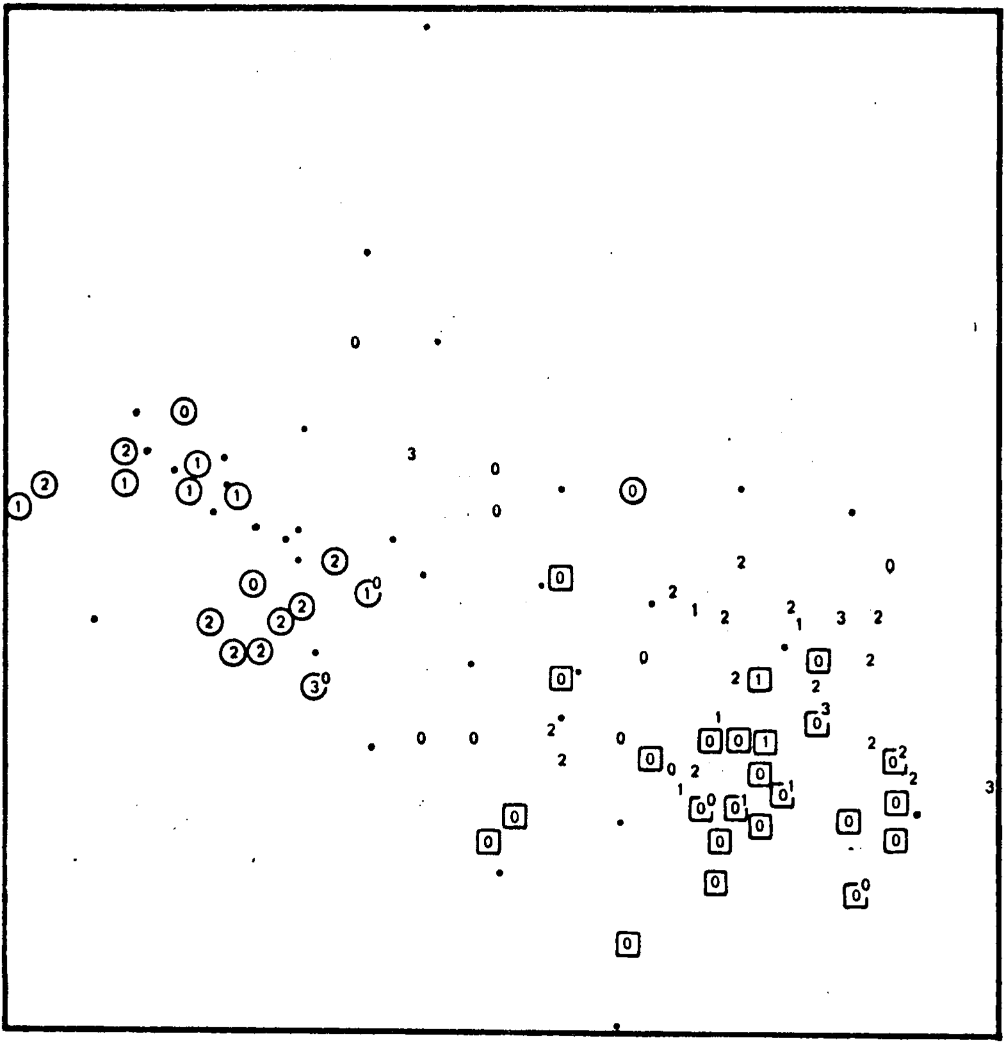


Fig 12: Distribution and cover-abundance values within the ordination of:

- 1 — Olea capensis subspecies capensis
- ① — Todea barbara
- [1] — Scutia myrtina
- . — All above species absent

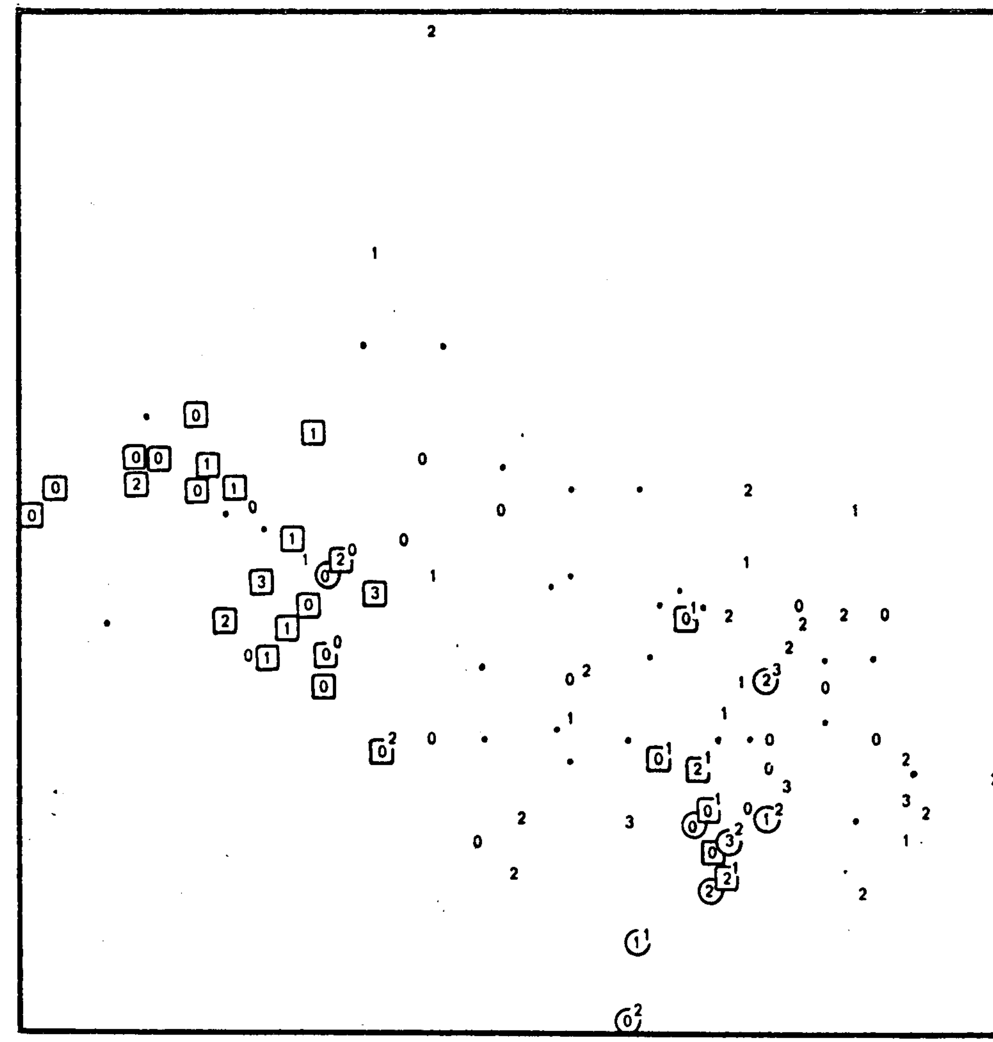


Fig 13: Distribution and cover-abundance values within the ordination of:

- 1 — Olinia ventosa
- ① — Gonioma kamassi
- [1] — Blechnum punctualatum
- . — All above species absent

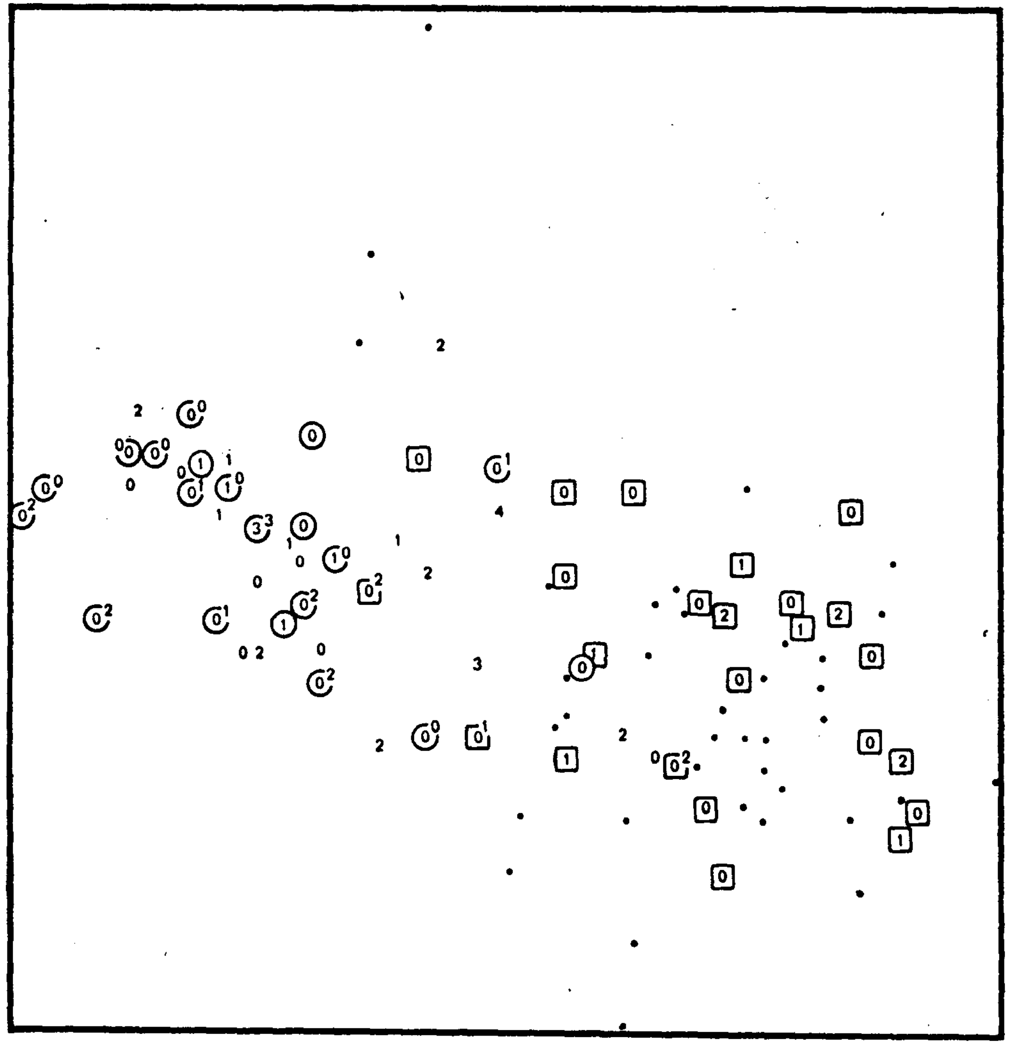


Fig 14: Distribution and cover-abundance values within the ordination of:

1 *Platylophus trifoliatus*
[1] *Cassinopsis ilciflora*
(1) *Blechnum attenuatum*
• All above species absent

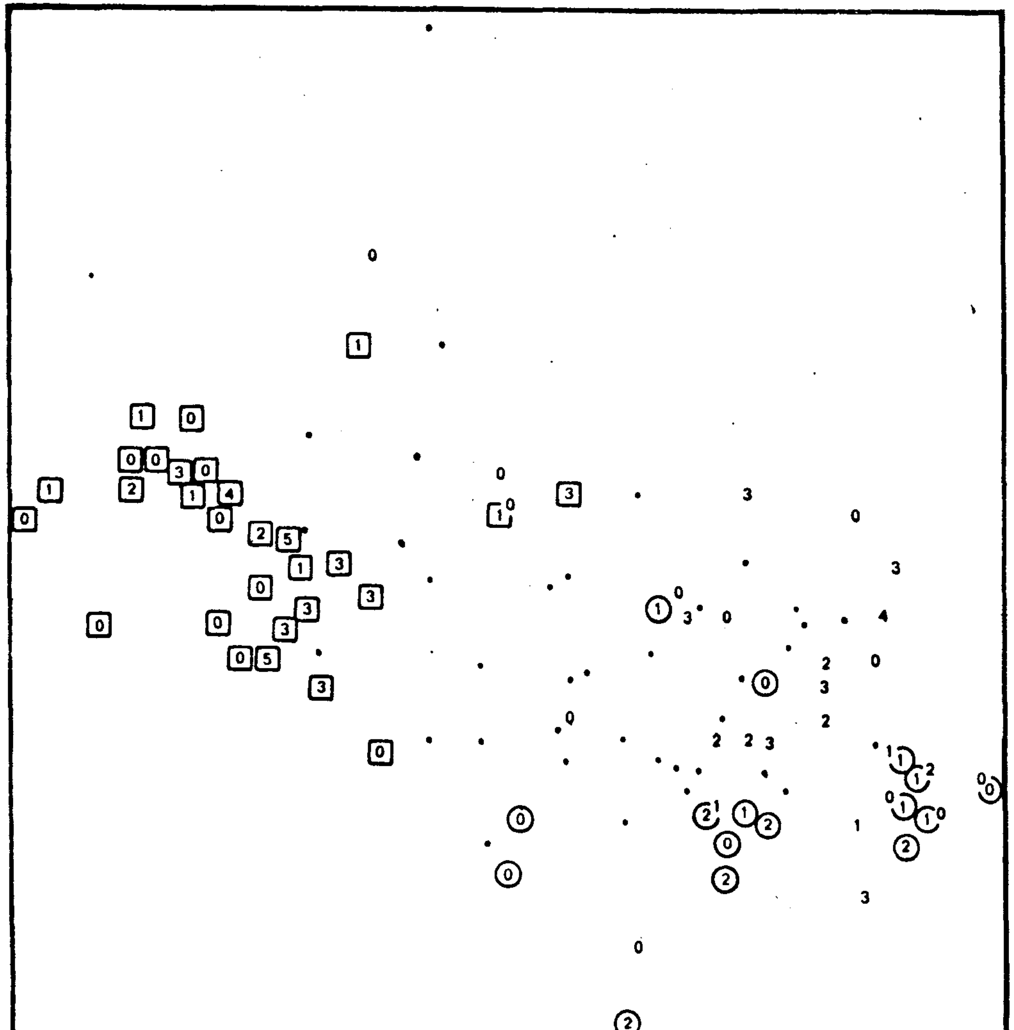


Fig 15: Distribution and cover-abundunce values within the ordination of:

- 1 *Cassine peragua*
- (1) *Burchellia bubalina*
- [1] *Alsophilla capensis*
- . All above species absent

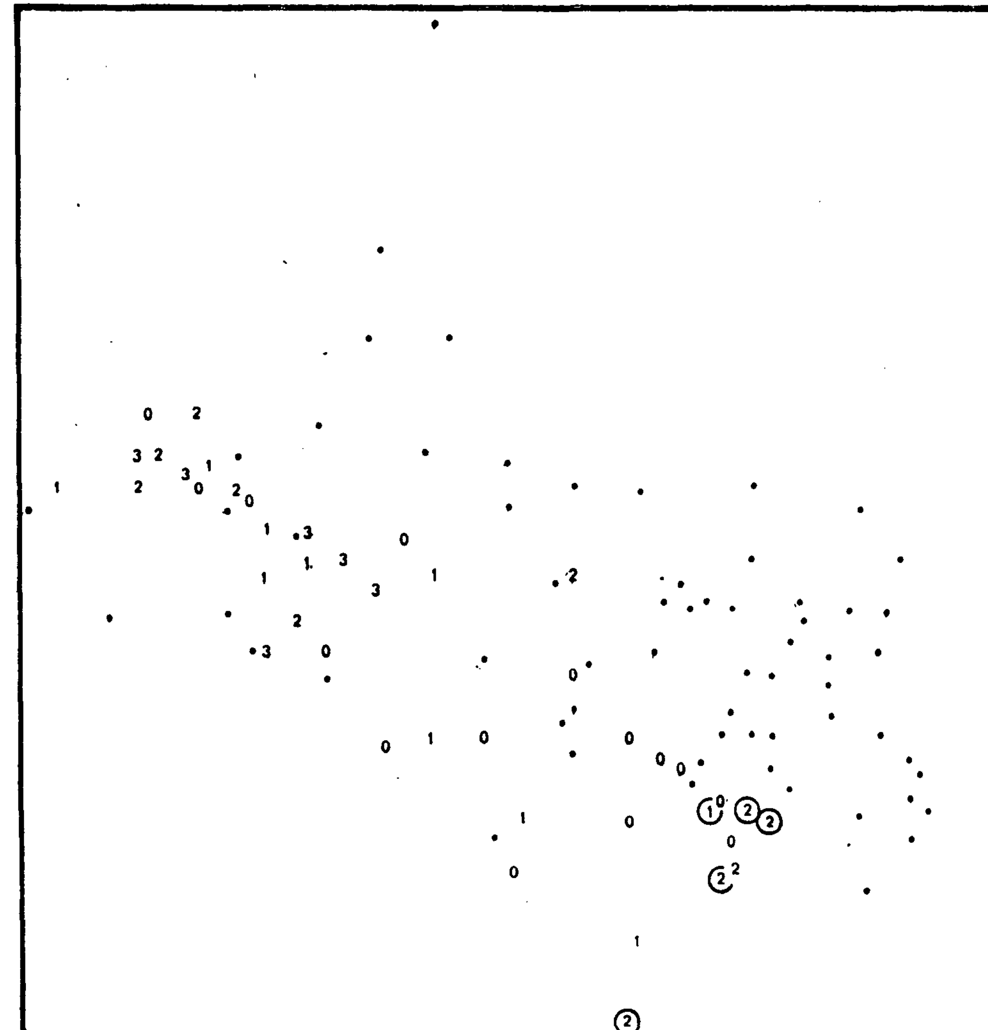


Fig 16: Distribution and cover-abundance values within the ordination of:

- 1 *Ocotea bullata*
- (1) *Trichocladus crinitus*
- . All above species absent

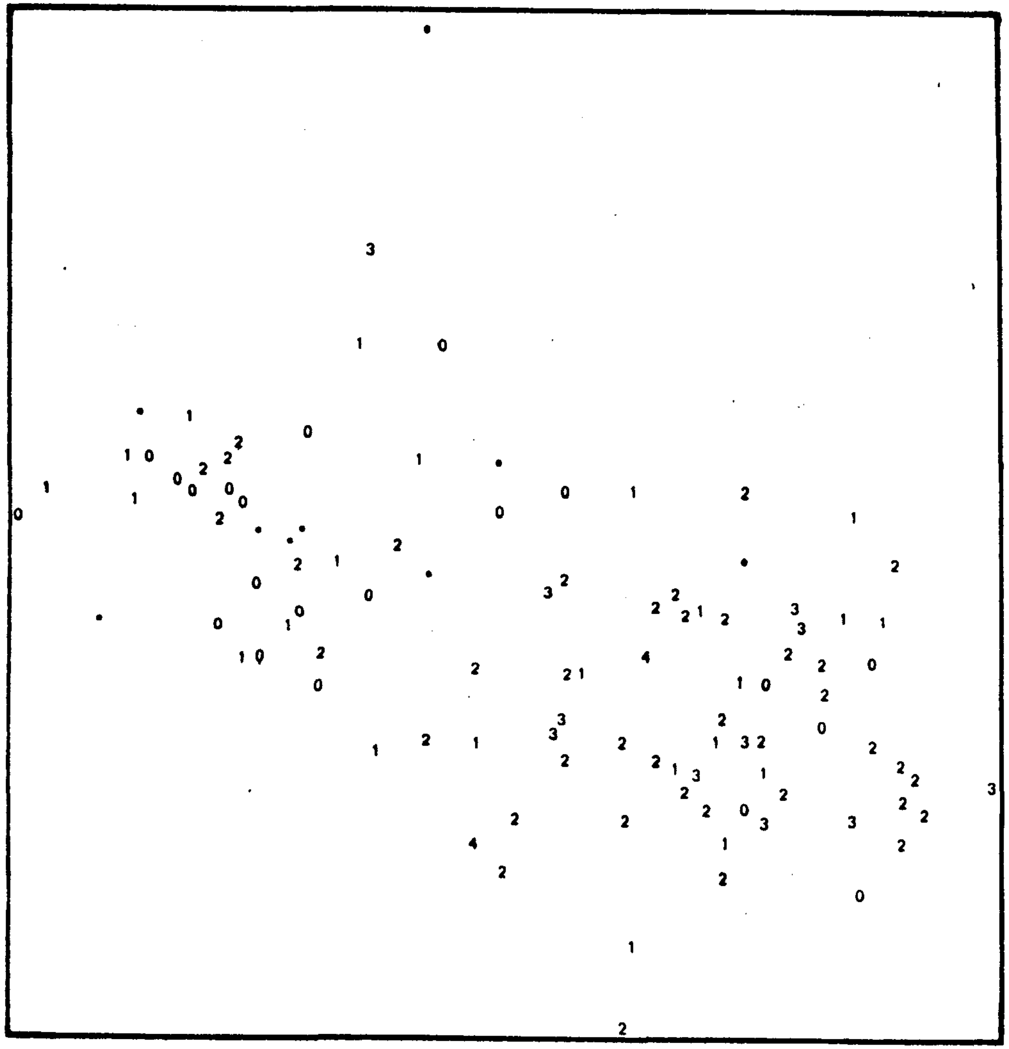


Fig 17: Distribution and cover-abundance values within the ordination of:

<u>Rapanea melanophloeos</u>
. Species absent

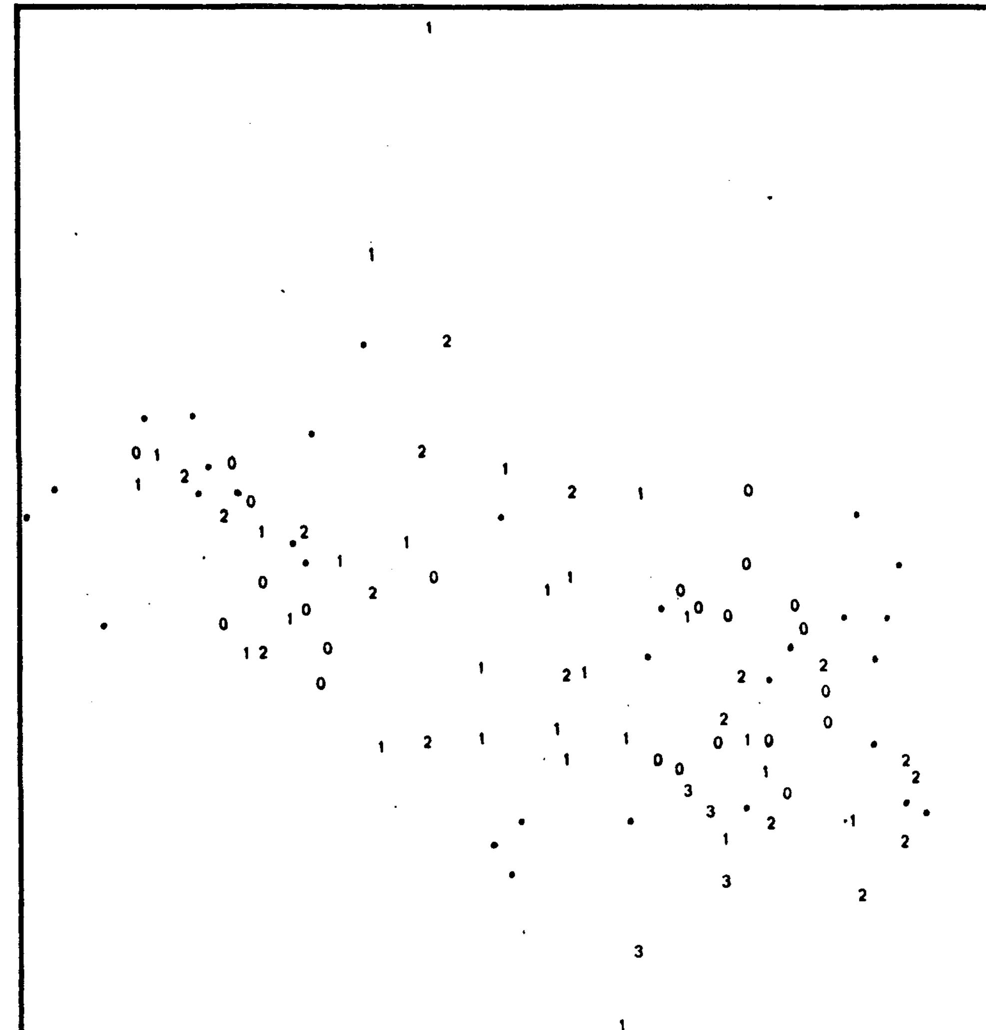


Fig 18: Distribution anc cover-abundance values within the ordination of:

<u>Podocarpus latifolius</u>
. Species absent

ordination diagram (see Fig. 7). Other species showing similar distribution patterns to the above are Clutia pulchella, Polystichum ammifolium and two Hymenophyllum spp. Ocotea bullata (see Fig. 16) although occurring in other communities has its highest cover-abundance values in this community. O. bullata, C. capensis and Platylophus trifoliatus are the more important canopy trees in this community. Rapanea melanophloeos and Podocarpus latifolius (see Figs. 17 and 18) are sometimes found in the canopy, but have relatively low cover-abundance values. These two species are, however, found in all communities from the wet type through to the drier types. Species with similar distribution patterns to the latter two species but mainly restricted to the sub-canopy and understorey layers are Hartogia schinoides, Kiggelaria africana, Maytenus accuminata and Halleria lucida.

The ground layer is dominated by the ferns already mentioned with A. capensis and sometimes T. barbara being included in the understorey layer.

8.3.2 (B) Cunonia capensis - Platylophus trifoliatus community

This community is very similar to the previous one differing mainly in that the ferns which were so important in the Cunonia capensis - Todea barbara community are either absent or rare. The ground and understorey layers are correspondingly less dense with a few species typical of drier forests occurring sporadically through this community. Cassinopsis ilciflora, an understorey shrub species of drier forest is an example (see Fig. 14). This community is in fact a link between the wet forest type (Cunonia capensis - Todea barbara community) and the drier forest types.

The canopy tree component is similar to that of the previous community, C. capensis, P. trifoliatus and O. bullata being prominent. However species which are important canopy trees in drier forests and usually absent or rare in the wet community are present in this community often only as sub-canopy trees though. Examples of this phenomena are Olinia ventosa, Olea capensis subsp. capensis, Rothmannia capensis and Cassine peragua (see Figs. 13, 12, 10 and 15).

The two general occurring species represented in the ordination diagrams Rapanea melanophloeos and Podocarpus latifolius fill a similar niche in this community as they did in the previous one. These two trees may however be more important constituents as far as cover-abundance is concerned. The trees with similar distribution patterns to the above are mainly sub-canopy trees but also have higher cover-abundance values than they did in the previous community.

8.3.3 (C) Gonioma kamassi - Nuxia floribunda community

This is a dry community confined to the Jonkersberg forest complex (see Figs. 8 and 9). The distribution of three species which characterize this community are shown on Figs. 13, 16 and 10. These three species Gonioma kamassi, Trichocladus crinitus and Nuxia floribunda along with Cassine papillosa, Trimeria grandifolia and Lachnostylis hirta are virtually exclusive to this forest community. This forest community only occurs in the eastern limits of the study area and if any of the species occur further west, they are very rare.

Possibly because of the presence of these species, others which are important in drier forests throughout the rest of the study area are less prominent. Olinia ventosa for example, generally has lower cover-abundance values in this community than the other dry forests (see Fig. 13). Similarly Rothmannia capensis, Cassine peragua and Olea capensis subsp. capensis, which are usually important indicator species of the drier forests are rather rare in this community. Burchellia bubalina (see Fig. 15) a species generally exclusive to dry forests has higher cover-abundance values and is more common in this community than the other dry forests.

Because of the difference in species composition the structure of this forest community also tends to be peculiar. T. crinitus, for example, is the dominant understorey tree and this could explain the relative paucity of Cassinopsis ilciflora (see Fig. 14) an important ground layer and understorey shrub of forests to the west. P. latifolius is another species which is particularly abundant in the understorey.

The two indicator canopy species of the wetter forests, Cunonia capensis and Platylophus trifoliatus are entirely absent from this community although Ocotea bullata, a common canopy tree in wet forest is found, but then has relatively low cover-abundance values. The common canopy tree species include Podocarpus latifolius, Rapanea melanophloeos, Olea capensis subsp. macrocarpa, Nuxia floribunda, Gonioma kamassi and Cassine papillosa.

The common sub-canopy trees are Hartogia schinoides, Burchelia bubalina, Rothmannia capensis, L. hirta, T. grandifolia and Pterocelastrus tricuspidatus.

The ground layer is extremely sparse and are not represented on the ordination as they are the less important indicators of this type of forest. The absence of "wet" ferns and the presence of the six tree species G. kamassi, T. crinitus, N. floribunda, C. papillosa, T. grandifolia and L. hirta is sufficient to distinguish this community from the wetter forests and the other dry forests respectively.

8.3.4 (D) Cassine peragua community

This is the driest forest community of the study area and is found throughout the region. Important species which characterise this community are *Cassine peragua* (see Fig. 15) and *Grewia occidentalis*. These two species are known to be characteristic of dry forests in the vicinity of the study area (Phillips, 1931; Taylor, 1955; von Breitenbach, 1974; Campbell and Moll, 1977). *Linociera foveolata* is another species seemingly characteristic of this community although also present in moister forests.

The more common canopy species are *C. peragua*, *Rapanea melanophloeos* and *Podocarpus latifolius*. The latter two are more abundant in the canopy in this community than any of the others (see Figs. 17 and 18). The canopy species are however numerous including both species of *Olea capensis*, *Hartogia schinoides*, *Pterocelastrus tricuspidatus* and *Diospyros whyteana*. The presence of the last mentioned species in the canopy is usually indicative of short (8m) dry forest as in more mesic forest it is usually only a sub-canopy or understorey species.

All the canopy species may be present in the sub-canopy which includes numerous other species including *Linociera foveolata*. The more abundant species in this layer are *Olea capensis* subsp. *capensis* and *Canthium ventosum*.

The understorey layer contains any of the species of the canopy or sub-canopy layer, the most abundant ones being *C. ventosum*, *C. mundianum*, *D. whyteana*, *L. foveolata* and *Halleria lucida*. The most interesting common understorey species however is *G. occidentalis*. This species is characteristic of dry forest and is often confined to this layer and the ground layer. In short dry forest it is found as a small stunted shrub on the ground.

Other typical species of the ground layer are *Scutia myrtina* (see Fig. 12) *Carissa bispinosa* and *Chlorophytum* sp. There are numerous other species which may be locally important but the ground layer is usually very poor.

8.3.5 (E) *Rothmannia capensis - Cassinopsis ilciflora* community

This community is typical of the majority of forests in the study area. It is relatively mesic when compared to the two drier types described. It is characterised by the lack of any particular dominant or common species. It has elements of both the wet forests and dry forests but lacks

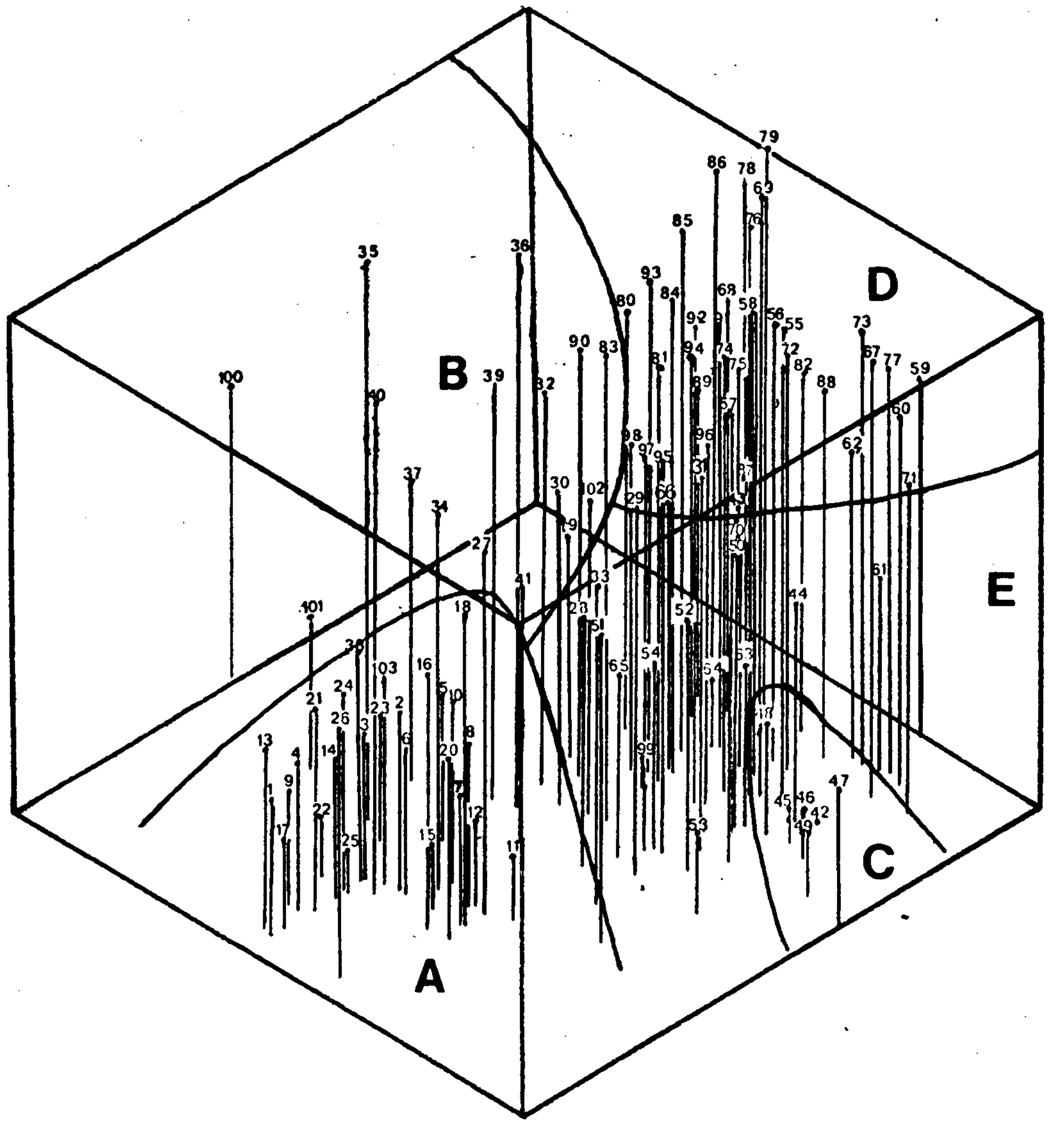


Fig 19: Distribution of the relevés within the secondary ordination. The isolines separate the five communities, A, B, C, D and E referred to in the text.

the species which specifically characterised those communities.

It is obvious from studying the ordination diagrams that this phenomena is apparent. "Wet" species such as Platylophus trifoliatus and Cunonia capensis are found sporadically in this community although they were absent from the dry types. Similarly species such as Scutia myrtina, Burchellia bubalina and Cassine peragua typical of dry forests are found here as well.

One species, Rothmannia capensis which is widely spread (see Fig. 10) has its highest cover-abundance values in this community. Similar species are the tree Pterocelastrus rostratus and the shrub Cassinopsis ilciflora.

The canopy, sub-canopy and understorey are thus varied and the majority of tree species which occur throughout the study region may be constituents of these layers. The ground layer is also diverse although it is usually very sparse.

8.4 SECONDARY ORDINATION

The secondary ordination with three axes failed to account for any variation in the central stands of the primary ordination (i.e. Rothmannia capensis - Cassinopsis ilciflora

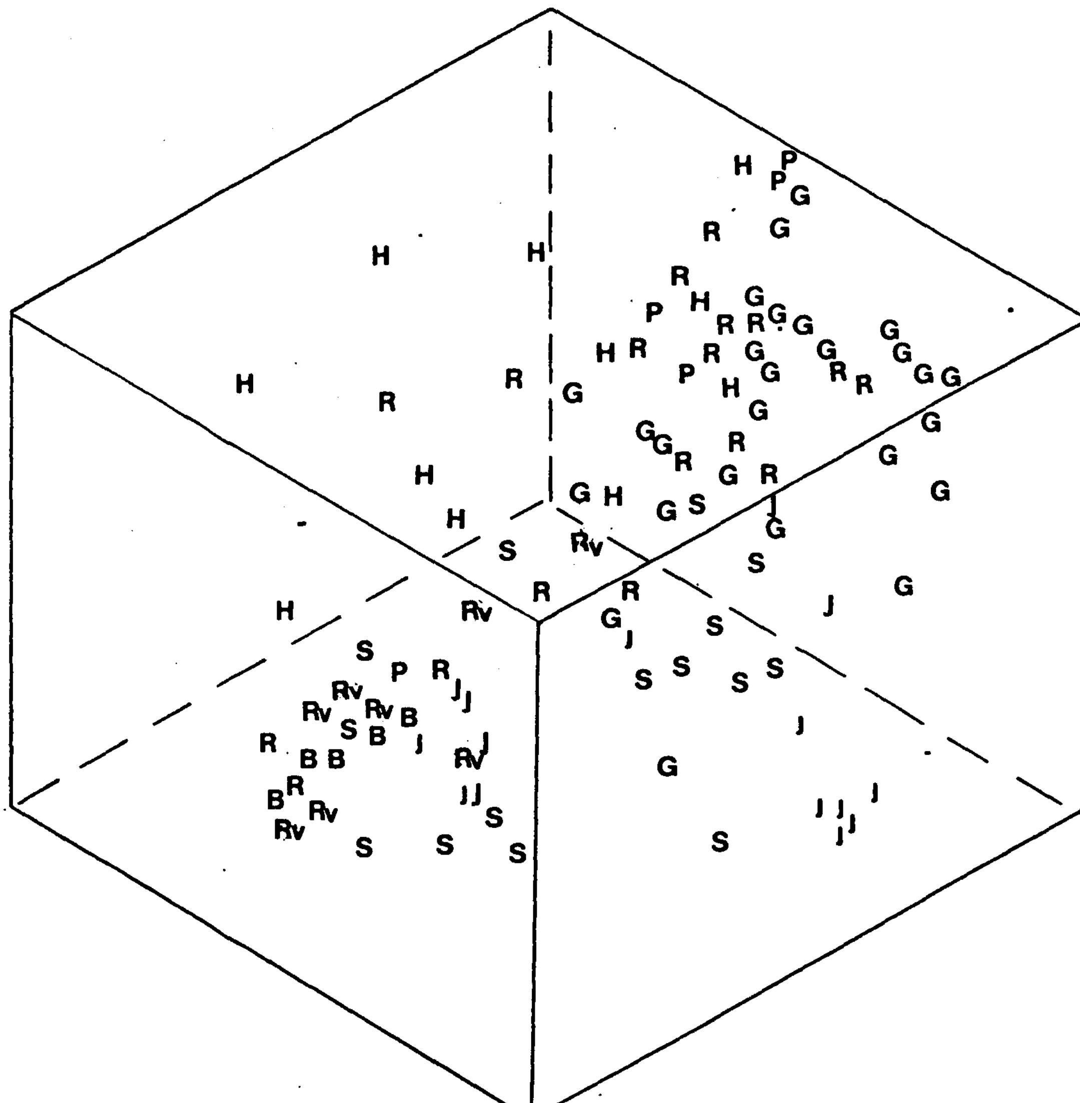


Fig 20: Secondary ordination showing the distribution of the forest complexes (J = Jonkersberg, Rv = Riversdale, G = Grootvadersbos, B = Boesmansbos, S = Swellendam, R = Riviersonderend, H = Hottentots Holland, P = Cape Peninsula)

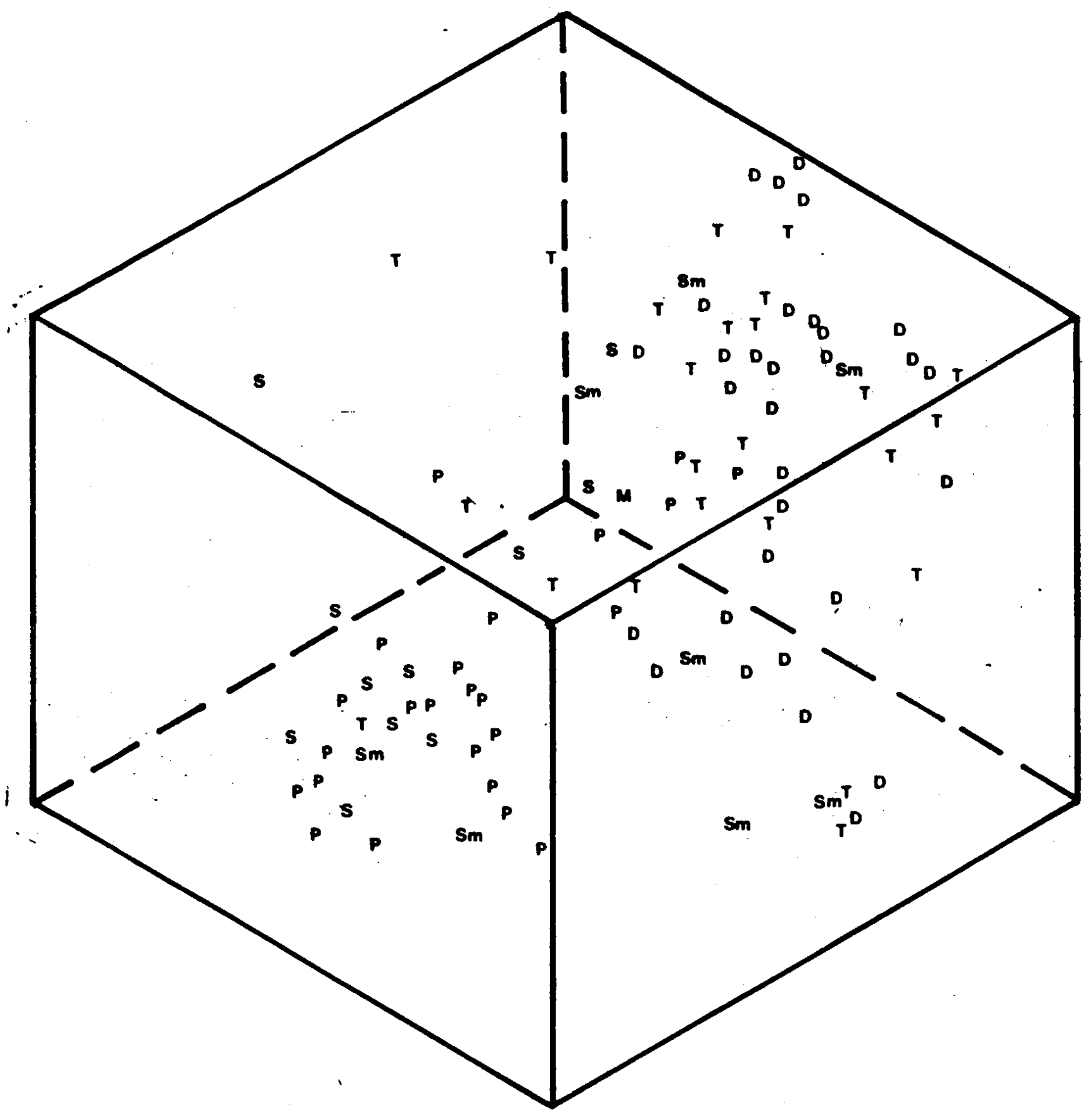


Fig 21: Secondary ordination showing the distribution of moisture status (P = permanently wet, Sm = seasonally moist, S = seasonally wet, M = permanently moist, T = temporarily moist, D = dry).

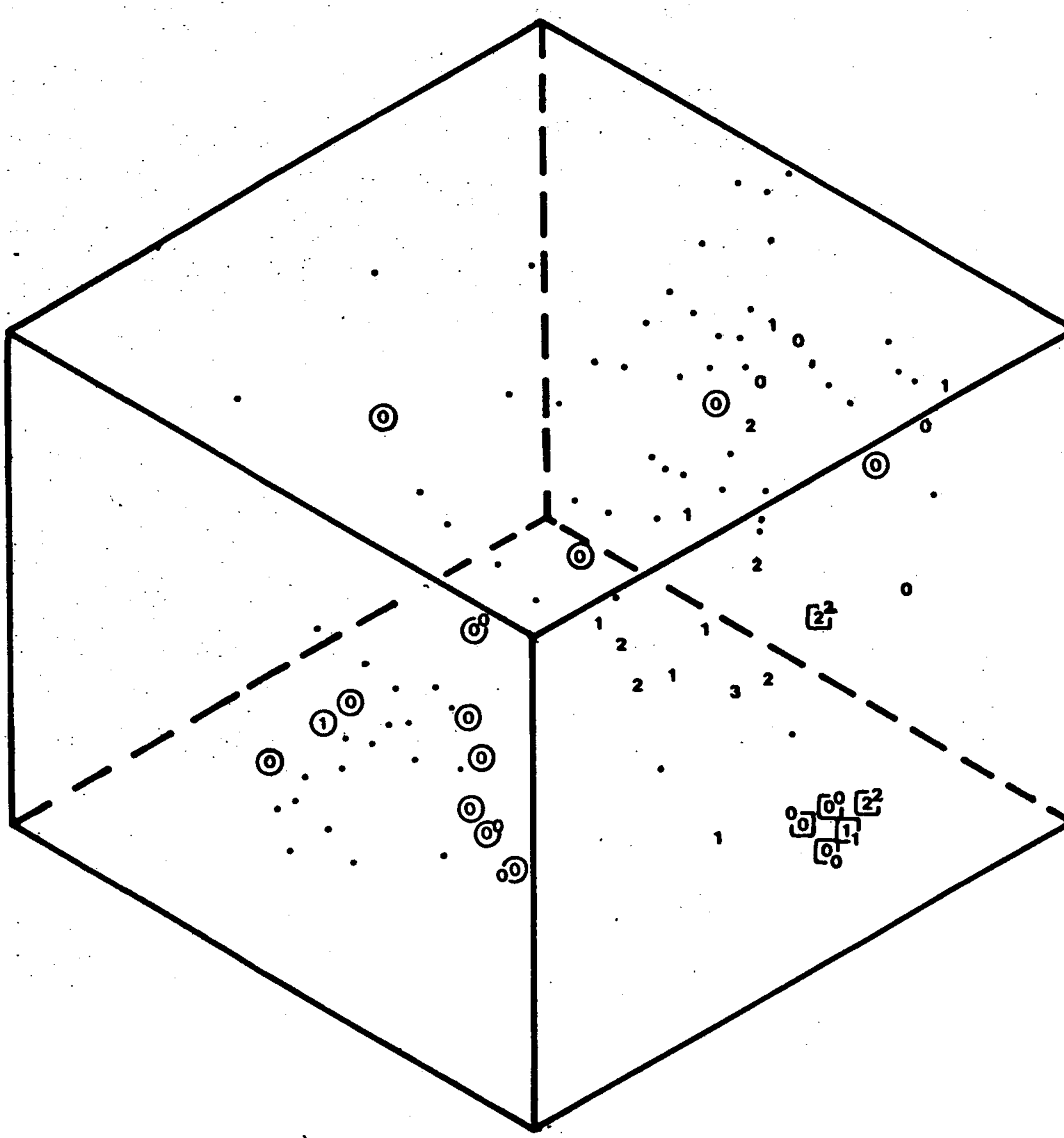


Fig 22: Distribution and cover-abundance values within the ordination of:

1 Rothmania capensis

(1) Blechnum capense

[1] Nuxia floribunda

. All above species absent

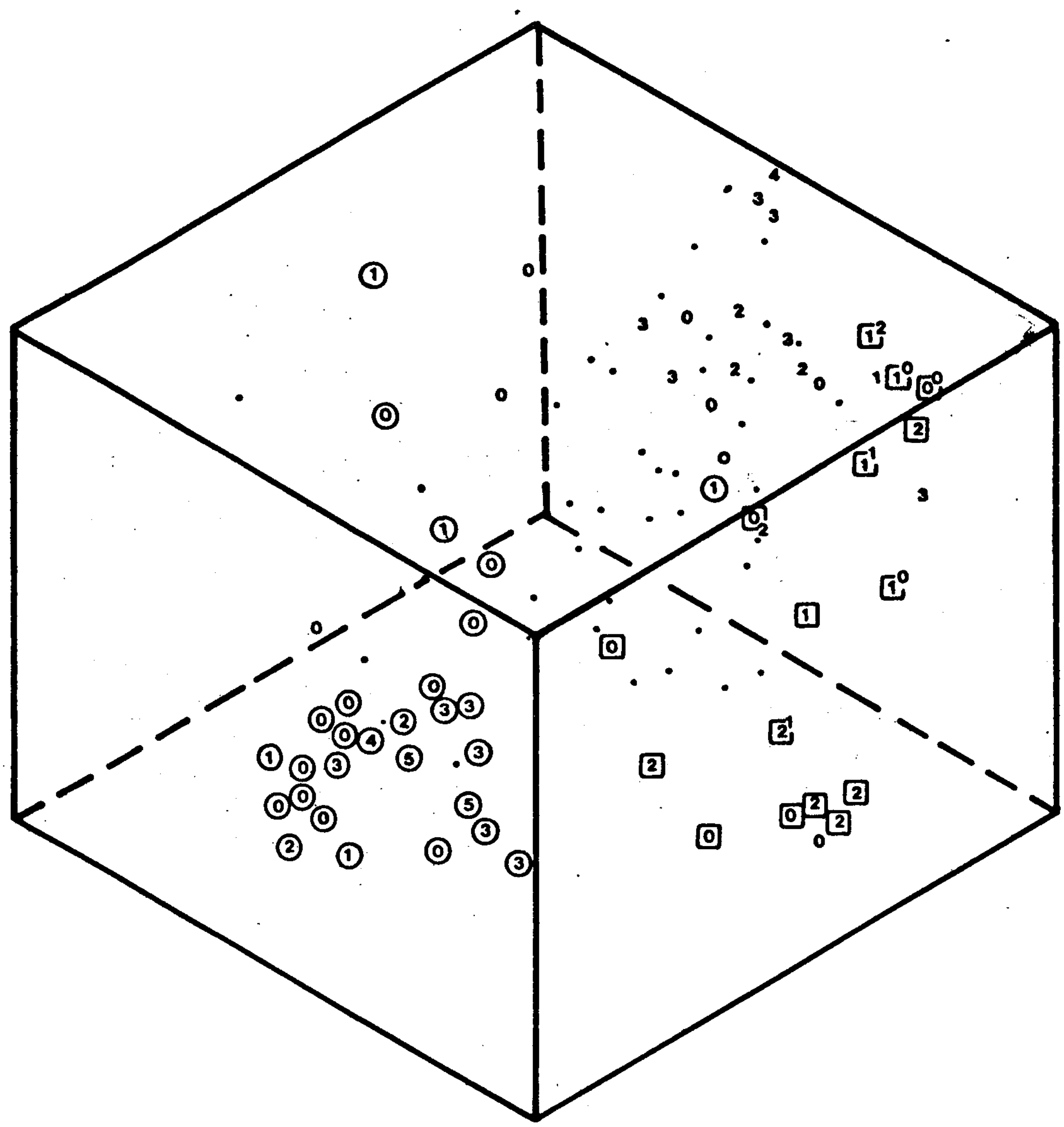


Fig 23: Distribution and cover-abundance values within the ordination of:

1 Cassine peraqua

(1) Alsophilla capensis

[1] Burchellia bubalina

. All above species absent

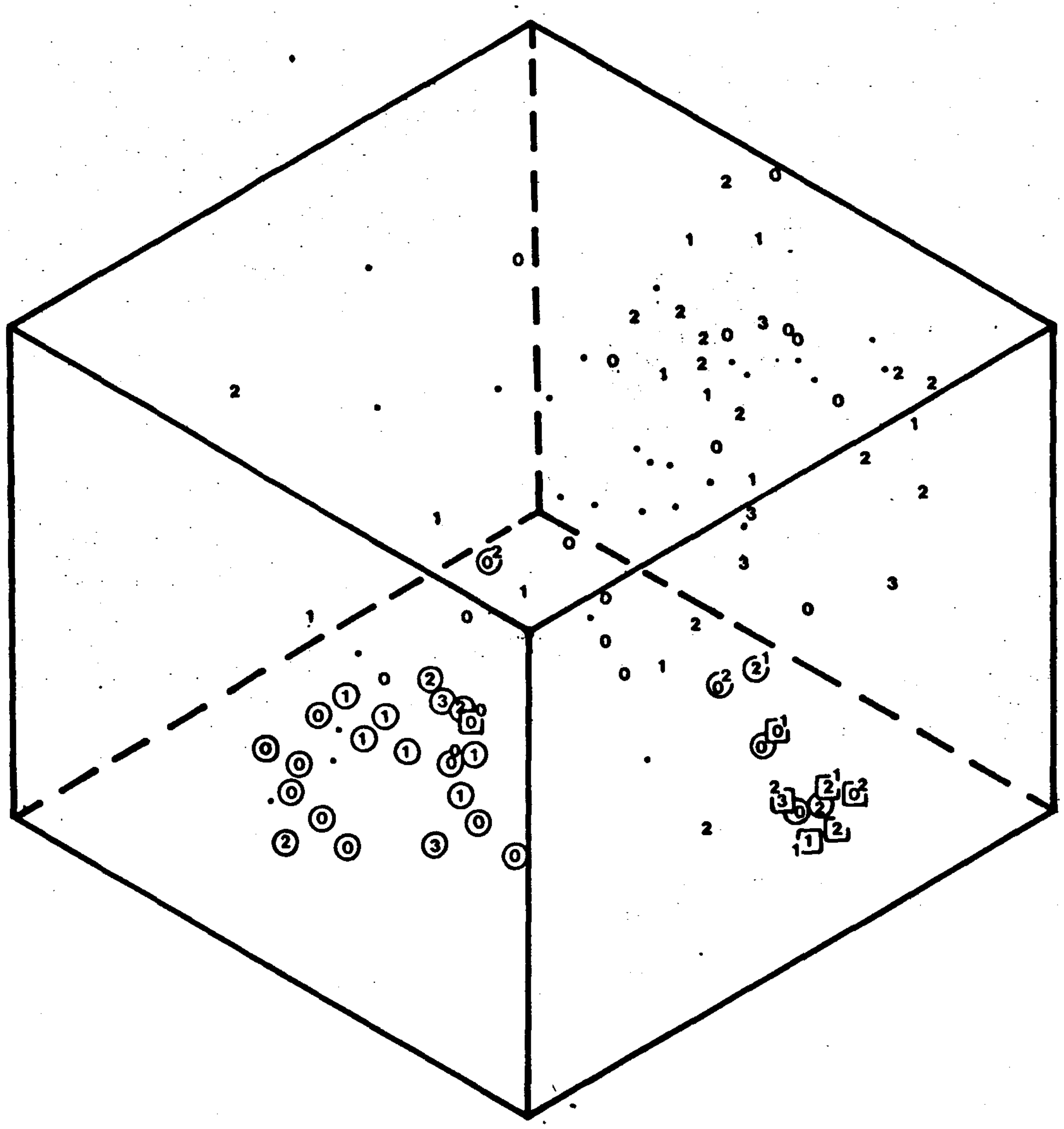


Fig 24: Distribution and cover-abundance values within the ordination of:

1 Olinia ventosa

[1] Gonioma kamassi

(1) Blechnum punctualatum

. All above species absent

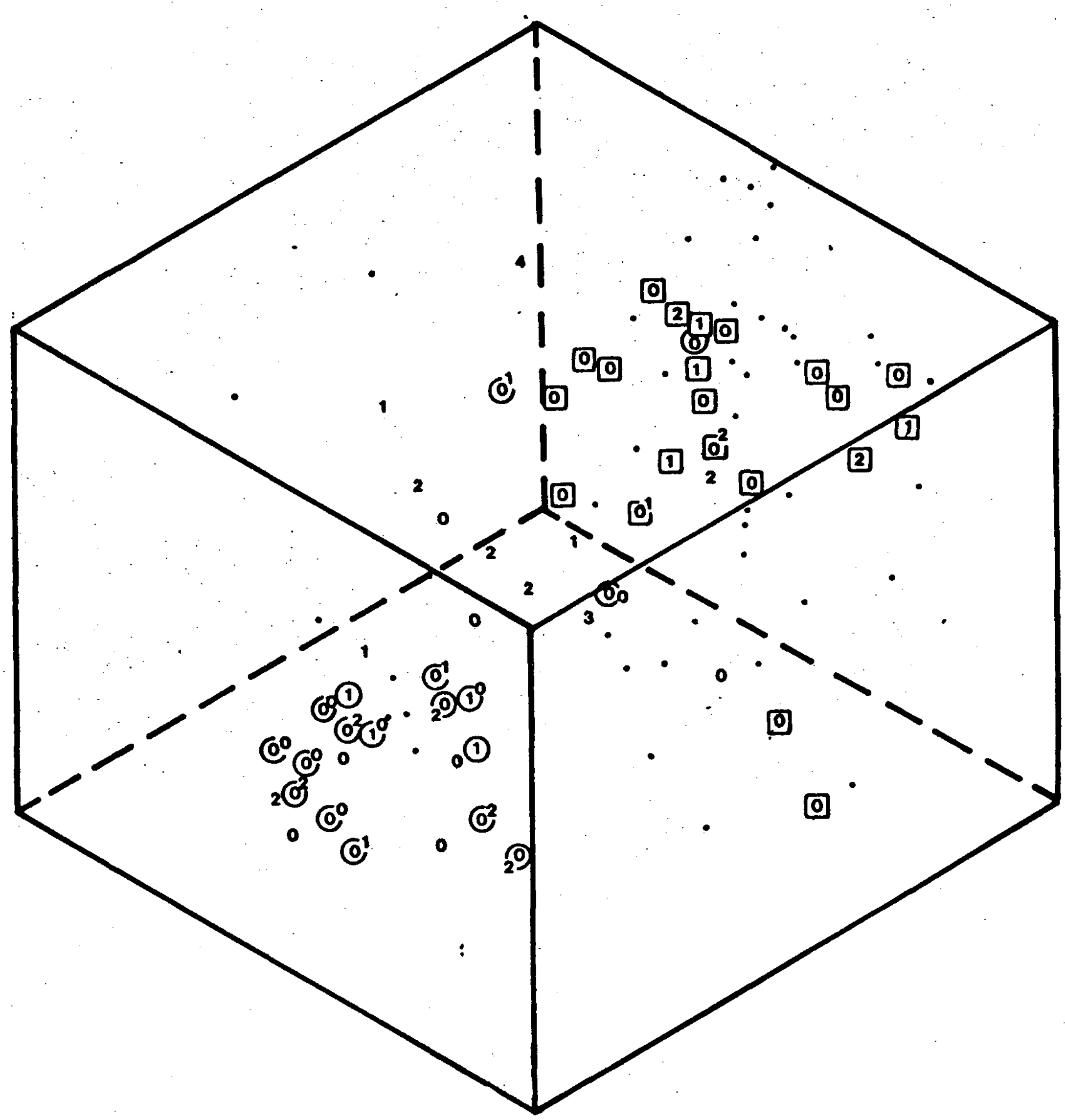


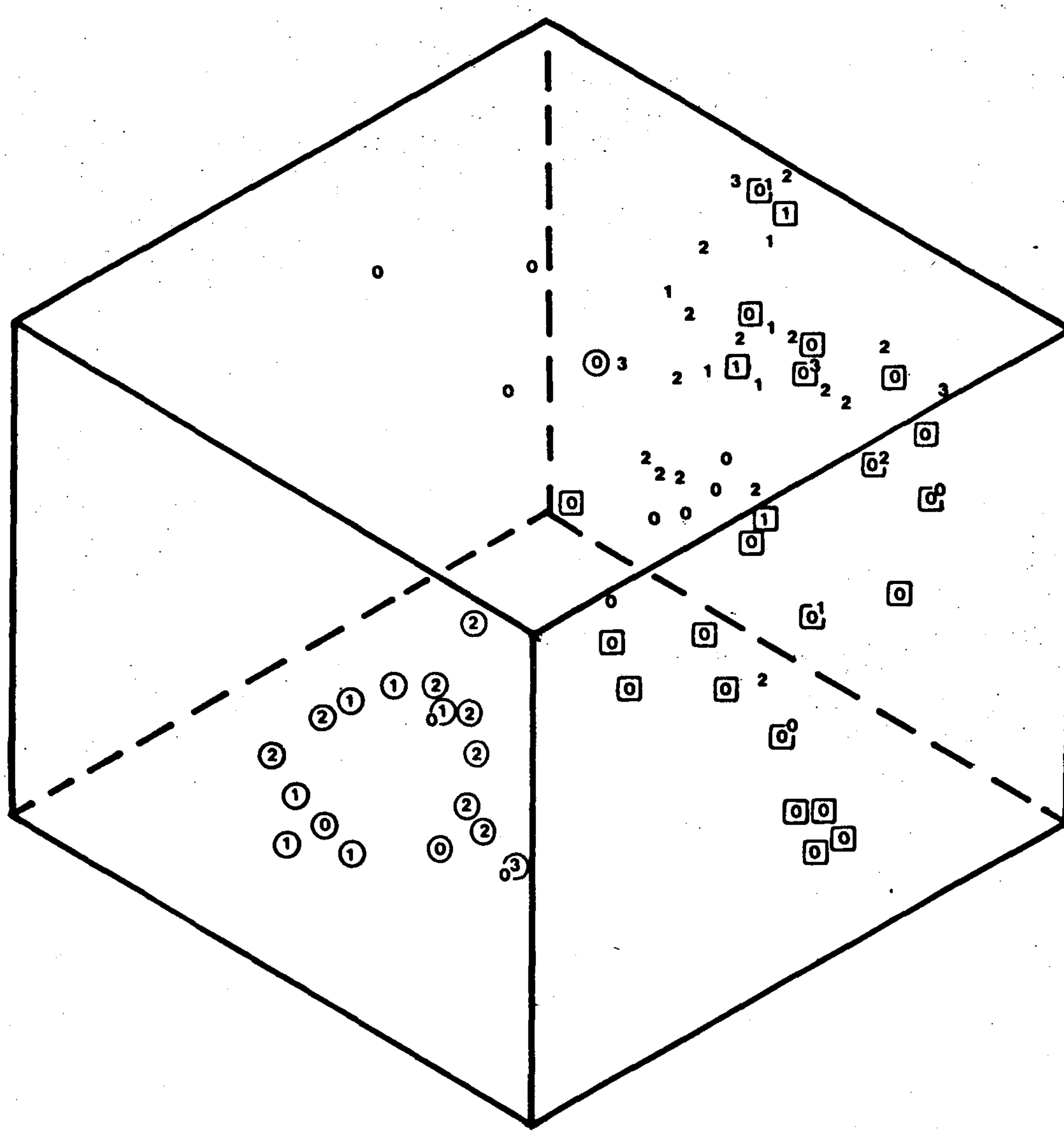
Fig 25: Distribution and cover-abundance values within the ordination of:

1 Platylophus trifoliatus

[1] Cassinopsis ilciflora

(1) Blechnum attenuatum

. All above species absent



Fiq 26: Distribution and cover-abundance values within the ordination of:

1 Olea capensis subspecies capensis

(1) Todea barbara

[1] Scutia myrtina

. All above species absent

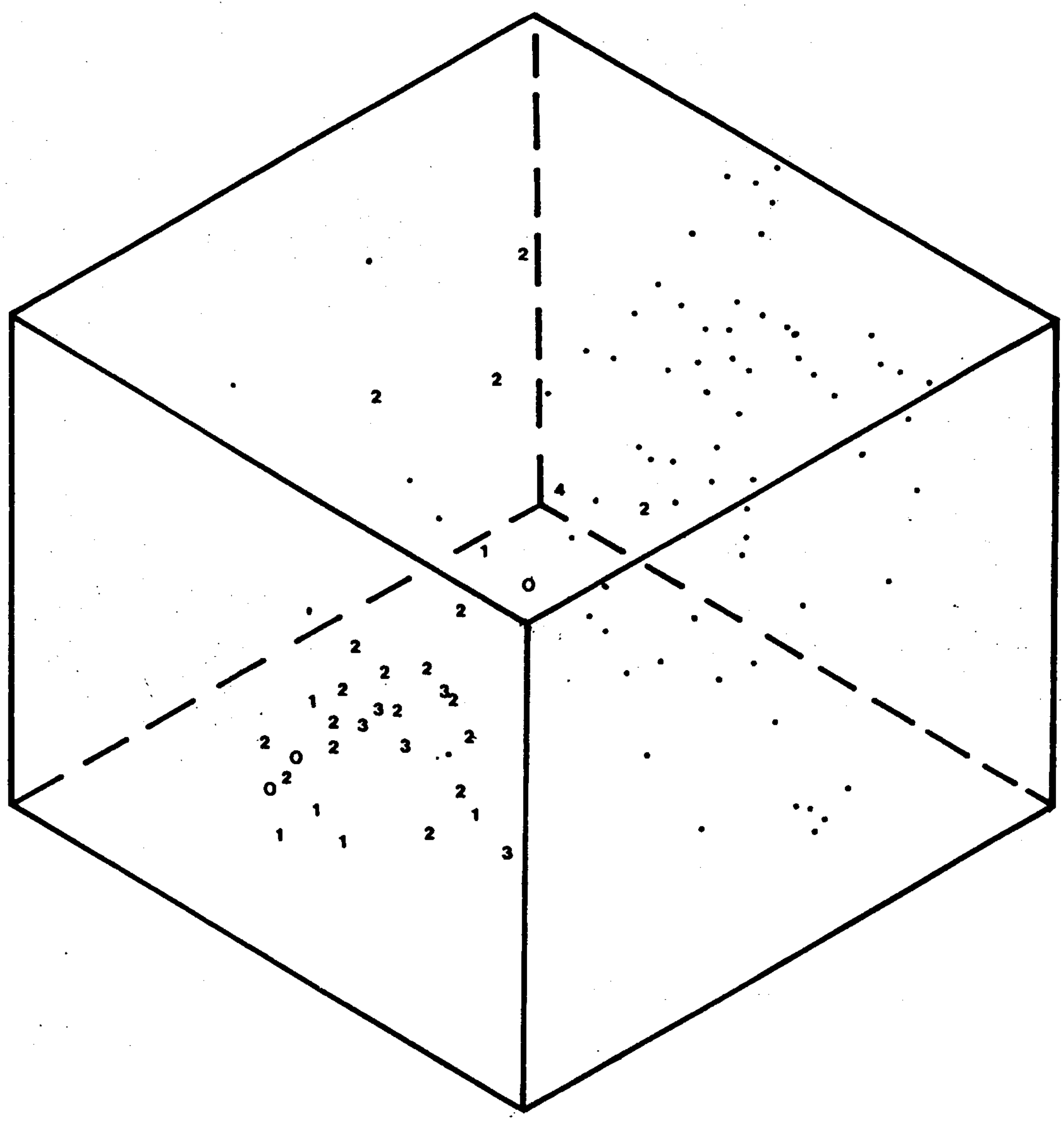


Fig 27: Distribution and cover-abundance values within the ordination of:

<u>Cunonia capensis</u>

. Species absent

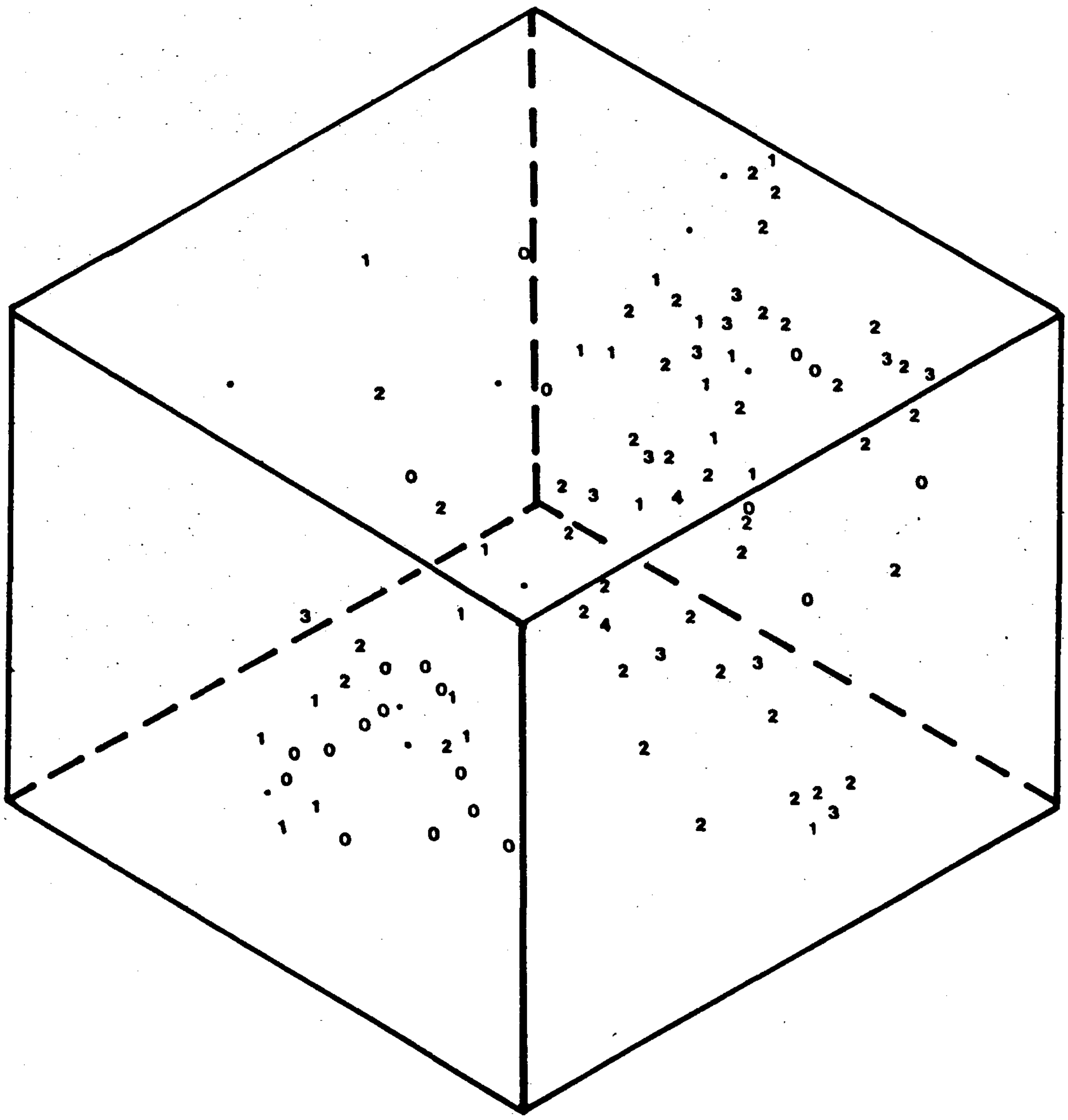


Fig 28: Distribution and cover-abundance values within the ordination of:

Rapanea melanophloeos

. Above species absent

community). The position of the releves within the secondary ordination are shown in Fig. 19, along with isolines showing the demarcation of five groups which are essentially the same units recognised in the primary ordination. The main feature of the secondary ordination is the separation and consolidation of the three communities which were clearly distinguishable in the primary ordination, namely the _Cunonia capensis_ - _Todea barbara_ community; the _Gonioma kamassi_ - _Nuxia floribunda_ community and the _Cassine peragua_ community.

The five groups recognised in the secondary ordination being essentially the same as the primary ordination are similarly named and called communities. The five communities are thus :

(A) _Cunonia capensis_ - _Todea barbara_ community
(B) _Cunonia capensis_ - _Platylophus trifoliatus_ community
(C) _Gonioma kamassi_ - _Nuxia floribunda_ community
(D) _Cassine peragua_ community; and
(E) _Rothmannia capensis_ - _Cassinopsis ilciflora_ community.

Considering that the ordination is essentially the same as that of the two dimensional one, only a few species with their respective cover-abundance values are represented on the ordination diagram. Similarly the only two discernible environmental factors determining these distributions, namely the locality and the moisture status of the stands are represented in Fig. 20 and Fig. 21.

It is unnecessary in view of the similarities of the two ordinations to describe the distribution of the species represented in the ordination. It will suffice to say here that the following species typical of wet forests are represented in the diagrams, namely, Cunonia capensis, Alsophilla capensis, Blechnum capense, B. punctualatum, Blechnum attenuatum, Platylophus trifoliatus and Todea barbara (see Figs. 27, 23, 22, 24, 25 and 26). Similarly species typical of dry forest, Cassine peragua, Burchellia bubalina, Scutia myrtina and Olea capensis subsp. capensis are shown in Figs. 23 and 26. Nuxia floribunda and Gonioma kamassi represent typical species of the Gonioma kamassi - Nuxia floribunda community (see Figs. 22 and 24). Olinia ventosa and Rothmannia capensis and Cassinopsis ilciflora are representative of species in intermediate forest (i.e. Rothmannia capensis - Cassinopsis ilciflora community) the former being more abundant in drier forest and the latter having its highest cover-abundance values in this intermediate forest (see Figs. 22, 24 and 25). Rapanea melanophloeos (Fig. 28) is an example of a general occurring species with higher cover-abundance values in the drier forest types.

It is obvious from studying the above distribution patterns that the ordination follows the two dimensional ordination closely. Similarly species with similar distributions to the above species and described in the primary ordination are peculiar to the various communities.

8.5 DISCUSSION

Primary and secondary ordination has succeeded in grouping releves with similar species compositions together and these can be related to the moisture status and/or the locality of the particular forest stand. Variations do occur across the ordination from wet sites through to dry sites even from the same locality. Centres of distributions occur both as a response to moisture status and locality, but certain species occur throughout the forests exhibiting dominant or common status under particular circumstances. These circumstances are not always easy to explain. For example, the most constant occurring species in the study area was Rapanea melanophloeos, but definitely had higher cover-abundance values in drier forests. This phenomena is probably due to competition from species (e.g. Cunonia capensis and Platylophus trifoliatus) characteristic of wet habitats and not the habitat itself.

The primary ordination indicated that it was only possible to group relevés on a broad basis and clustered the relevés in the centre of the ordination where there were few characteristic species. The secondary ordination proved unable to account for the variability between the relevés of the central cluster and produced an ordination essentially similar to the primary ordination. The main feature of the secondary ordination was the separation and consolidation of the major groups recognised in the primary ordination.

CHAPTER IX

DISCUSSION : ORDINATION AND CLASSIFICATION

It is not the intention here to discuss the controversy over the relative merits of classification and ordination, but rather to discuss some relevant points from the present work.

The present work has indicated the close relationship that exists between the two methods, although ordination has sometimes been considered as an alternative to classification. This basic supposition is based on the fact that mathematical synthesis of data as employed in the present ordination leads to a more objective presentation of results while the grouping of stands into classes can show a discreteness that may not really exist in nature. However, as the present survey has indicated the two processes are separate but intimately linked whereby ordination could be considered as a step prior to classification. Mueller-Dombois and Ellenberg (1974) consider that the "ordering or ordination of species and stands is a necessary step prior to any good classification". Of course the ways of ordering the data may vary considerably from simple ranking to sophisticated factor analysis.

This survey has in fact indicated that for studying vegetation of the nature of this thesis over a wide geographical range that the classification process is preferable. The five groups recognised in the ordination can be identified with one or more units recognised in the phytosociological table, but the technique has not the flexibility of the Braun-Blanquet approach. The Braun-Blanquet approach allows for easy description of anomalous relevés within groups and explanations as to its difference can be deduced far more easily from a table which gives the total floristic composition and all the environmental factors considered. The ordination method used does not allow for the easy recognition of anomalous relevés and a lot of species and environmental factors would have to be placed on the ordination to discern reasons for any such anomalies. This has been quite obvious in the present study where three sub-associations and eight variations have been recognised in the phytosociological survey. Within the various variations individual relevés have been singled out for special mention due to some important parameter which has made it unique. This, of course, is not easy to do for in the ordination technique, although this method had some advantages over the Braun-Blanquet method with regard to species distributions. One advantage that was evident from the ordination technique and especially with the three dimensional (secondary) ordination, is that clustering tendencies of stands can be shown geometrically and species quantities can be correlated with the clusters. An example is the cover-abundance ratings for Rapanea melanophloeos. Although this species occurred throughout the stands in the ordination it was very clear that its lowest cover-abundance values were in the "wet" forest stands. This type of information is far easier to obtain from an ordination than a table, provided the ordination produces reasonably clear clusters. The actual choice of the clusters is in fact subjective and as in the tabular method the final interpretation becomes one of personal judgement and assessment.

In fact in this study the objectivity of the ordination technique has been reduced considerably. Firstly the placement of plots was subjective, secondly cover-abundance ratings were subjective, thirdly the choice of end stands was subjective and finally the delimiting of groups in the ordination was done by personal judgement. Nevertheless besides the cluster recognition both ordinations served to identify trends in the forest variation which led to explanation in terms of environmental gradients. However, the technique failed in a number of instances to clearly separate species with restricted distributions, often placing them in close proximity to stands where the species is absent. This can be misleading in interpreting such phenomena, and here again the elasticity of the classification procedure used made interpretation easier.

Both techniques, however, have succeeded in showing the variation to be found within the forests of the south-western Cape. The intention of this thesis was not to map the units recognised but to indicate the variation within these forests which were generally thought to lack species dominance and consequently to be complex in their floristic composition. The classificatory approach is considered to have the advantages over the ordination technique in this particular study.

CHAPTER X

QUANTITATIVE CHARACTERISTICS

10.1 INTRODUCTION

The classification and ordination approaches used present only qualitative data on species presence and abundance. In order to get a more quantitative idea of the role of species in various strata, density data was also collected. The number of individuals (stems) of each woody species in the canopy, sub-canopy and understorey were counted in each of the releves used for the classification and ordination study.

The division into canopy, sub-canopy and understorey was done subjectively in each particular stand. There are always problems in using this approach, as there is always a certain amount of straddling and this can lead to confusion as to exactly which strata an individual belongs. It was impossible to use height or girth measurements for a more objective approach. This was because the height of the forest stands themselves varied tremendously through the study area, tall wet forest being up to 35m tall and short dry forest only 8m tall.

The choice of site and plot size and general sampling procedure was thus the same as used for the classification study.

Densities of all woody species with a density of at least 20 per hectare for one or more strata are shown in Tables 9 and 10. Table 9 gives the mean density of major woody species in the three strata for wet forest, while Table 10 gives the similar information for dry forest.

Wet and dry forest have been divided subjectively here, wet forest including the majority of relevés from the Cunonia capensis - Todea barbara community and the Cunonia capensis - Platylophus trifoliatus community recognised in the secondary ordination (see Fig. 19). The dry forest densities were calculated from the majority of the relevés representing the Gonioma kamassi - Nuxia floribunda community; the Cassine peragua community and the Rothmannia capensis - Cassinopsis ilciflora community recognised in the secondary ordination (see Fig. 19).

This division was used in preference to calculating density values for individual forest complexes or specific communities for a number of reasons. Firstly, insufficient data was collected from some of the complexes to divide the forest into wet and dry forest and obtain a meaningful result. Secondly, dividing the forest up into communities for the quantitative assessment was thought to be too rigid considering the amount of overlap and integration between communities. The decision to divide the forest into only two classes; wet and dry, was done because these are definitely distinguishable whereas any further sub-division on moisture status would again lead to a greater degree of overlapping.

Thus considering these two basic forest types for the study region as a whole gives an indication of the importance of the dominant species in the various strata. It will become evident that even with species tailing off from east to west the general quantitative characteristics of the important species as far as density is concerned, will manifest themselves.

10.2 RESULTS AND DISCUSSION

Table 9 clearly indicates that the more dense canopy species in wet forest are Cunonia capensis, Platylophus trifoliatus, Ocotea bullata, Ilex mitis, Pterocelastrus rostratus, Rapanea melanophloeos and Podocarpus latifolius. C. capensis is the dominant tree having a density of nearly double the next most important tree, P. trifoliatus. The presence of P. rostratus in the above list is significant. This tree is usually a sub-canopy tree in wetter forest but its relatively high density value is

TABLE 9

MEAN DENSITY PER HECTARE OF MAJOR CANOPY, SUB-CANOPY AND UNDERSTOREY TREES IN WET FOREST

SPECIES	CANOPY DENSITY	SUB-CANOPY DENSITY	UNDERSTOREY DENSITY
Cunonia capensis	130	17	11
Platylophus trifoliatus	66	22	17
Ocotea bullata	64	11	138
Ilex mitis	52	14	22
Pterocelastrus rostratus	36	130	194
Rapanea melanophloeos	36	41	30
Podocarpus latifolius	22	27	77
Apodytes dimidiata	5	25	11
Hartogia schinoides	14	47	91
Halleria lucida	10	34	44
Maytenus accuminata	3	31	63
Diospyros whyteana	0	11	33
Olea capensis subsp. capensis	5	19	25
Olea capensis subsp. macrocarpa	6	19	86
Curtisia dentata	5	8	22
Alsophilla capensis	0	0	136

indicative that a large portion of the wet forests do not reach any great heights (i.e. greater than 25m). P. latifolius, which is so important in the Knysna (Phillips, 1931) and Natal (Moll, 1971) forests is only the seventh most important species as far as density is concerned. This could be due to overexploitation as this yellowwood was much sort after by the early settlers (Hartwig, 1973).

P. rostratus is by far the most important sub-canopy tree, having a density of 130 per hectare. Hartogia schinoides and R. melanophloeos are also relatively important, R. melanophloeos having its highest density in this layer.

The more important understorey species are P. rostratus, Alsophilla capensis, O. bullata, H. schinoides, P. latifolius Olea capensis subsp. macrocarpa and Maytenus accuminata. A. capensis (the forest tree fern) is of course only present in this strata and has a high density (136 individuals/ hectare). Of interest in this layer is the relatively high densities of two important canopy trees, namely, O. bullata (black stinkwood) and P. latifolius (yellowwood). These two species have been sought after and are still today important timber trees (Hartwig, 1973). Their over-exploitation in the past may account for their relatively

TABLE 10

MEAN DENSITY PER HECTARE OF MAJOR CANOPY, SUB-CANOPY AND UNDERSTOREY TREES IN DRY FOREST

SPECIES	CANOPY DENSITY	SUB-CANOPY DENSITY	UNDERSTOREY DENSITY
Rapanea melanophloeos	168	38	16
Olinia ventosa	69	22	20
Cassine peragua	69	40	5
Podocarpus latifolius	55	60	83
Olea capensis subsp. capensis	35	30	35
Pterocelastrus tricuspidatus	31	28	11
Hartogia schinoides	31	21	20
Apodytes dimidiata	24	32	36
Diospyros whyteana	10	21	50
Trichocladus crinitus	0	0	69
Canthium ventosum	15	25	20
Rothmannia capensis	13	24	44

low densities in the sub-canopy and in the case of P. latifolius in the canopy. Protection afforded the forests today may be instrumental in changing their importance in the canopy and sub-canopy layers and their high densities in the understorey may be an indication of the change taking place. A similar trend is seen in the density values for O. capensis subsp. macrocarpa (ironwood) also an important timber tree.

The two tree species which are particularly indicative of wet forests namely C. capensis and P. trifoliatus have very low density values in the understorey layers. This could be an indication that these forests are drying out and the wetter species not being as successful as others.

Table 10 indicates that R. melanophloeos, Olinia ventosa, Cassine peragua and P. latifolius are the more important canopy species of drier forest. R. melanophloeos and P. latifolius are of course two of the most general occuring species throughout the relevés analysed (see Table 8). They are important species in both wet and dry forests.

Both these species have higher densities in the canopy in drier forest than wet forest. This is an interesting phenomenon because the drier forests are the more accessible and would have been expected to be more heavily exploited than the wetter inaccessible forests. An explanation for this discrepancy could be due to the competition in wet forest stands from species like C. capensis, P. trifoliatus, I. mitis and O. bullata (all of which are absent or have densities of less than 20/hectare in dry forests).

C. peragua is relatively important in the canopy as is the other species of Pterocelastrus; P. tricuspidatus. Olea capensis subsp. capensis also has higher density velues than it did in the wet forest.

There is not the relative dominance in the sub-canopy of the dry forest as there was in the wet forest, all the important canopy species having the relative same densities with the exception of R. melanophloeos and Olinia ventosa.

The understorey layer is where interesting changes occur. The four most important species here are Trichocladus crinitus (onderbos), P. latifolius, Diospyros whyteana and Rothmannia capensis. T. crinitus is restricted to this layer and is entirely absent from the sub-canopy and canopy layers. Its relative high density is significant when it is considered that this species is restricted to the Jonkersberg forest complex. This high density gives an indication of its importance and the high densities it must have in the Jonkersberg and Knysna forests generally. D. whyteana is a typical understorey tree and very occasionally found in the canopy as is R. capensis, although both may have relative high densities in the sub-canopy. C. peragua an important canopy and sub-canopy species has very low densities in the understorey while other species such as H. schinoides, Apodytes dimidiata and Canthium ventosum carry equal densities for all strata.

It is evident from the above discussion and the comparison of Table 9 and 10 that the wet and dry forests have particular species in each layer which are dominant and the two types have very few important species in common. R. melanophloeos, P. latifolius, H. schinoides and A. dimidiata are fairly important in both types but as mentioned above their importance varies in the different strata of the two types.

REFERENCES

Acocks, J.P.H. 1953. Veld Types of South Africa. Mem. Bot. Surv. S. Afr. 28.

Adamson, R.S. 1927. The plant communities of Table Mountain. 1. Preliminary account. J. Ecol. 15 : 278-309.

Adamson, R.S. 1948. Some geographical aspects of the Cape Flora. Trans. Roy. Soc. S. Afr. 31 : 437-469.

Adamson, R.S. 1951. Buried trees on the Cape Flats. Trans. Roy. Soc. S. Afr. 33 : 13-24.

Annonymous 1970. Geological Map of the Republic of South Africa and the Kingdoms of Lesotho and Swaziland. Government Printer Pretoria.

Beals, E. 1960. Forest bird communities in the Apostle Islands of Wisconsin. Wilson Bull. 72 : 156-181.

Bews, J.W. 1921. Some general principles of plant distribution as illustrated by the South African flora. Ann. Bot. 35 : 1-36.

Boucher, C. 1972. The vegetation of the Cape Hangklip area. Unpubl. M.Sc. thesis, University of Cape Town.

Braun-Blanquet, J. 1932. Plant sociology. (transl. G.D. Fuller and H.S. Conrad). McGraw Hill, New York.

Braun-Blanquet, J. 1965. Plant sociology. (transl., rev. and ed. G.D. Fuller and H.S. Conrad). Hafner, London.

Bray, R.J. and Curtis, J.T. 1957. An ordination of the upland forest communities of southern Wisconsin. Ecol. Monogr. 22 : 325-349.

Cain, S.A. and Castro, G.M. de O. 1959. Manual of Vegetation Analysis. Harper, New York.

Campbell, B.M. and Moll, E.J. 1976. On numerical methods for classifying releves collected in Braun-Blanquet phytosociological surveys. J.S. Afr. Bot. 42, 1 : 45-56.

Campbell, B.M. and Moll, E.J. 1977. The forest communities of Table Mountain, South Africa. Vegetatio Vol. 34, 2 : 105-115.

CHAPTER XI

CONCLUSION

Both the classification and ordination procedures used have proved successful in studying the forests of the south-western Cape. The intention of the study; to find the variation in the forests of the study area was achieved, the classification procedure allowing more flexibility than the ordination technique. The two processes by and large produced the same results indicating that they are complementary; the classification approach being preferable for this type of study due to its greater flexibility and the usefulness of a final phytosociological table for comparison of total floristic richness between communities.

The forests can be grouped into a number of types based on their floristic composition which is related to moisture status and locality. The important characteristic in classifying the forests lay in the tailing off of species from east to west; this phenomena being more important in drier forests. The wet forests are more or less similar throughout the study zone.

Cover-abundance and density data have indicated the importance of certain species in the various forests and within the different strata recognised.

Campbell, B.M. and Moll, E.J. 1976. Towards a rapid method for determining optimum plot size. Botany Dept., University of Cape Town. (unpubl).

Ceska, A. and Roemer, H. 1971. A computer programme for identifying species - releve groups in vegetation studies. Vegetatio, 23 : 255-277.

Ceska, A. and Roemer, H. 1976. Ceska-Roemer program for identifying species - releve groups. Biology Department, University of Victoria, Canada (unpubl).

Clark, J.D. 1959. The prehistory of Southern Africa. Pelican Books, London.

Clements, F.C. 1936. Nature and structure of the climax. J. Ecol. 24 : 252-284.

Coetzee, B.J. and Werger, M.J.A. 1973. On hierarchial syndrome analysis and the Zurich - Montpellier table method. Bothalia 11 : 159-164.

Coetzee, B.J. 1974. A phytosociological classification of the vegetation of the Jack Scott Nature Reserve. Bothalia, 11, 3 : 329-347.

Coetzee, B.J. 1975. A phytosociological classification of the Rustenberg Nature Reserve. Bothalia, 11, 4 : 561-580.

Cooke, H.B.S. 1962. The pleistocene environment in South Africa. Hypothetical vegetation in Southern Africa during the pleistocene. Ann. Cape Prov. Mus. 11.

Cooper, K.H. and Moll, E.J. 1966. Hlogwene Forest. African Wildlife, 20, 4 : 321-326.

Curtis, J.T. 1959. The vegetation of Wisconsin : An ordination of plant communities. Univ. of Wisconsin Press, Madison.

Curtis, J.T. and McIntosh, R.P. 1951. An upland forest continuum in the prairie-forest border region of Wisconsin. Ecol. 32 : 476-496.

du Toit, A.L. 1954. The Geology of South Africa. Oliver and Boyd, London.

Dyer, R.A. 1975. The Genera of Southern African flowering plants. Vol 1. Dicotyledons. Dept. of Agricultural Technical Services.

Dyer, R.A. 1976. The genera of Southern African flowering plants. Vol. 2 Gymnosperms and Monocotyledons. Dept. of Agricultural Technical Services.

Edwards, D. 1967. A plant ecology survey of the Tugela Basin. Mem. Bot. Surv. S. Afr. 36.

Ellenberg, H. and Mueller-Dombois, D. 1967. Tentative physiognomic classification of plant formations of the earth. Ber. Geobot. Inst. Eth. Stifg. Rubel Zurich. 37 : 21-55.

Ellis, F. 1973. Soil studies in the Duiwenhoeks River catchment area. Unpubl. M.Sc. thesis, University of Stellenbosch.

Fosberg, F.R. 1961. A classification of vegetation for general purposes. Tropical Ecology 2 : 1-28.

Gauch, H.G. and Whittaker, R.H. 1972. Comparison of ordination techniques. Ecol. 53 : 868-875.

Gauch, H.G. 1976. Cornell Ecology Program 4. Ecology and Systematics, Cornell University, Ithaca, New York.

Gleason, H.A. 1926. The individualistic concept of the plant association. Bull. Torrey. Botan. Club. 53 : 7-26.

Good, R. 1964. The geography of flowering plants. Longmans, London.

Goodall, D.W. 1952. Quantitative aspects of plant distribution. Biol. Rev. 27 : 194-245.

Goodall, D.W. 1954. Vegetational classification and vegetational continua. Pflanzensoziologie (Vienna) Festsckrift Aichinger 1 : 168-182.

Goodall, D.W. 1970. Statistical plant ecology. Ann. Rev. of Ecol. and Syst. 1 : 99-124.

Greig-Smith, P. 1964. Quantitative plant ecology. Butterworths, London.

Hamilton, G.N.G. and Cooke, H.B.S. 1965. Geology for S.A. students. Central News Agency Ltd., S. Africa.

Hartwig, G.L.T. 1973. Early uses of indigenous wood in Immelman, W.F.E., Wicht, C.L. and Ackerman, D.P. (Ed.) Our Green Heritage. Tafelberg.

Hendey, Q.B. 1975. Fossil occurrencies at Langebaanweg, Cape Province. Nature 244 : 13-14.

Hendey, Q.B. 1976. The Pliocene fossil occurrencies in 'E' quarry, Langebaanweg, South Africa. Annals. S. Afr. Mus. 69.

Henkel, J.S. 1912. The indigenous high forest situated in the Divisions of George, Knysna and Humansdorp, Cape Province. S. Afr. J. Sci. 9 : 68-76.

Heyns, A.J. 1957. Flora, fenologie en regenerasie van 'n inheemse woudgemeenskap naby Stellenbosch. J. S. Afr. Bot. 23 : 111-119.

Hopkins, B. 1955. The species area relations of plant communities. J. Ecol. 43 : 409-426.

Immelman, W.F.E., Wicht, C.L. and Ackerman, D.P. 1973. Our Green Heritage. Tafelberg.

Jackson, S.P. and Tyson, P.D. 1971. Aspects of weather and climate over Southern Africa. Environmental Studies, Occ. Paper 6, Univ. Witwatersrand.

Keay, R.W.J. 1959. Vegetation map of Africa south of the Tropic of Cancer. Oxford University Press, London.

Kershaw, K.A. 1973. Quantitative and dynamic plant ecology. Edward Arnold, London.

Kessel, S.R. and Whittaker, R.H. 1976. Comparisons of three ordination techniques. Vegetatio. Vol. 32, 1 : 21-29.

Kerfoot, O. 1968. Mist precipitation on vegetation. For. Abstracts, 29 : 8-20.

Killick, D.J.B. 1958. An account of the plant ecology of the Table Mountain area of Pietermaritzburg, Natal. Mem. Bot. Surv. S. Afr. 32.

Killick, D.J.B. 1962. An account of the plant ecology of the Cathedral Peak area of the Natal Drakensberg. Mem. Bot. Surv. S. Afr. 34.

Klein, R.G. 1971. Preliminary report on the July through September 1970, excavation of Nelson Bay Cave, Plettenberg Bay (Cape Province, S.A.). Palaeecology of Africa, 6 : 177-208.

Klein, R.G. 1974. Environment and subsistence of prehistoric man in the Southern Cape Province, South Africa. World Archaeol., 5 : 249-284.

Kruger, F.J. 1974. The physiography and plant communities of Jakkalsrivier catchment. Unpubl. M.Sc. thesis, Univ. of Stellenbosch.

Kruger, F.J. 1978. South African heathlands. In R.L. Specht (Ed.) Heathlands of the World. Elsevier, Amsterdam, (in press).

Laughton, F.S. 1937. The sylviculture of the indigenous forests of the Union of South Africa, with special reference to the forests of the Knysna region. Dept. of Agric. and For. Sci. Bull. 157.

Levyns, M.R. 1938. Some evidence bearing on the past history of the Cape flora. Trans. Roy. Soc. S. Afr. 26 : 401-424.

Levyns, M.R. 1950. Relations of the Cape and Karoo floras near Ladismith, Cape. Trans. Roy. Soc. S. Afr. 32 : 235-246.

Levyns, M.R. 1952. Clues to the past in the Cape flora of today. S. Afr. J. Sci. 49 : 155-164.

Levyns, M.R. 1957. The phytogeography of members of Protaeceae in Africa. J. S. Afr. Bot. 24 : 1-9.

Levyns, M.R. 1964. Migrations and origins of the Cape flora. Trans. Roy. Soc. S. Afr. 37 : 85-107.

Loxton, R. 1962. A simplified soil survey procedure for farm planning. Dept. Agric. Tech. Services, Pta.

Marloth, R. 1904. Results of experiments on Table Mountain for ascertaining the amount of moisture deposited from the south east clouds. Trans. S. Afr. Phil. Soc., 14 : 403.

Marloth, R. 1907. Results of further experiments on Table Mountain for ascertaining the amount of moisture deposited from the south east clouds. Trans. S. Afr. Phil. Soc., 16: 97-105.

Martin, A.R. 1955. Preliminary report on Groenvlei. Palaeoecology of Africa. Vol. 1.

McLachlan, D. and Moll, E.J. 1976. A report on fire and vegetation on Table Mountain. J.S.Afr.For.,99:7-12

McKenzie, B., Moll, E.J. and Campbell, B.M. 1976. A suggested management plan for the indigenous vegetation of Orange Kloof, Table Mountain, based on a phytosociological Survey. J.S.Afr.For.,99:1-6

McKenzie, B., Moll, E.J. and Campbell, B.M.1977. A phytosociological study of Orange Kloof, Table Mountain, South Africa. Vegetatio 34 : 41-53.

Moll, E.J. 1965. An account of the plant ecology of the Upper Mgeni catchment. Unpubl. M.Sc. thesis, Univ. Natal.

Moll, E.J. 1968a. A quantitative ecological investigation of the Krantzkloof Forest, Natal. J. S. Afr. Bot. 34, 1 : 15-25.

Moll, E.J., 1968b. An account of the plant ecology of the Hawaan Forest, Natal. J. S. Afr. Bot. 34, 2 : 61-76.

Moll, E.J. 1969. An investigation of the plant ecology of the Hawaan Forest, Natal, using an ordination technique. Bothalia, 10, 1 : 121-128.

Moll, E.J. 1971. Vegetation studies in the Three Rivers Region, Natal. Unpubl. Ph.D. thesis, Univ. Natal.

Moll, E.J. 1972. The current status of Misbelt Mixed Podocarpus forest in Natal. Bothalia, 10, 4 : 595-598.

Moll, E.J. and Haigh, H. 1966. A report on the Xumeni Forest, Natal. For. S. Afr. 7 : 99-108.

Moll, E.J. and Woods, D.B. 1971. The rate of forest tree growth and a forest ordination at Xumeni, Natal. Bothalia, 10, 3 : 451-460.

Moll, E.J., McKenzie, B. and McLachlan, D. 1978. A possible explanation for the lack of trees in the Cape (in prep.)

Mueller-Dombois, D. and Ellenberg, H. 1974. Aims and methods of vegetation ecology. John Wiley and Sons, London.

Muir, J. 1929. The vegetation of the Riversdale area, Cape Province. Mem. Bot. Surv. S. Afr. 13.

Nagel, J.F. 1956. Fog precipitation on Table Mountain. Quart. J. Roy. Met. Soc. 82 : 452-460.

Nagel, J.F. 1961. Rainfall in the Table Mountain area with special reference to orographic effects. Notos W.B. 10 : 59-73.

Nagel, J.F. 1962. Fog precipitation on Africa's south-west coast. Notos, 11 : 51-60.

Neethling, J.H. 1970. Classification of some forest soils of the Southern Cape. Unpubl. M.Sc. thesis, Univ. of Stellenbosch.

Phillips, J.F.V. 1926. Rainfall interception by plants. Nature, London.

Phillips, J.F.V. 1931. Forest - succession and ecology in the Knysna region. Mem. Bot. Surv. S. Afr. 14.

Phillips, J.F.V. 1970. Features in the identification of some commoner physiognomic types to be seen in South, South-eastern, South-western and Central Africa. Univ. Natal. (unpubl.).

Robertson, C.C. 1924. The forests of South Africa. Empire Forestry Journal, London. No. 1 Vol. III

Rourke, J.P. 1972. Taxomonic studies on Leucospermum R. Br. J. S. Afr. Bot. Suppl. 8.

Rogers, D.J. and Moll, E.J. 1975. A quantitative description of some coast forests of Natal. Bothalia. 11, 4 : 523-537.

Rumney, G.R. 1968. Climatology and the world's climate. Macmillan, New York.

Russel, E.J. 1973. Soil conditions and plant growth. Longman, London.

Rust, I.C. 1967. On the sedimentation of the Table Mountain Group in the Western Cape Province. Unpubl. Ph.D. thesis, Univ. Stellenbosch.

Rycroft, H.B. 1944. The Karkloof Forest, Natal. J. S. Afr. For. Assoc. 11 : 14-25.

Schalke, H.J.W.G. 1973. The Upper Quartenary of the Cape Flats area. (Cape Privince, S.A.). Scripta Geol. 15 : 1-43.

Schelpe, E.A.C.L.E. 1969. A revised check-list of the Pteridophyta of Southern Africa. J. S. Afr. Bot. 35, 2 : 127-140.

Schulze, B.R. 1965. Climate of South Africa. Part 8. General Survey S.A. Weather Bur. 28, Govt. Printer, Pretoria.

Schweitzer, F.R. and Scott, K.J. 1973. Early occurrence of domestic sheep in sub-Saharan Africa. Nature, 241.

Shimwell, D.W. 1971. The Description and Classification of Vegetation. Sidgwick and Jackson, London.

Sim, T.R. 1907. The forests and forest flora of the Cape Colony. Taylor and Henderson, Aberdeen.

Smith-Baillie, A.L., Rudman, R.B., Oosthuizen, A.B., Ellis, F. and Dohse, T.E. 1976. Soil survey of the Cape Peninsula. Soil and Irrigation Research Institute. Report No. 837/33/76.

Soil Classification Working Group, 1976. Soil classification. A. binomial system. Dept. of Agric. Tech. Serv., Pretoria.

Spilhaus, M.W. 1950. Indigenous Trees of the Cape Peninsula. Juta and Co., Ltd. Cape Town.

Talbot, W.J. 1947. Swartland and Sandveld. Oxford University Press, Cape Town.

Tankard, A.J. 1976. Pleistocene History and coastal morphology of the Ysterfontein - Elands Bay area, Cape Province. Ann. S. Afr. Mus., 69 : 73-119.

Tansley, A.G. 1929. Editorial note. J. Ecol. 17 : 147-7.

Taylor, H.C. 1955. Forest types and floral composition of Grootvadersbos. J. S. Afr. For. Assoc. 26 : 33-46.

Taylor, H.C. 1961. Ecological account of a remnant coastal forest near Stanford, Cape Province. J. S. Afr. Bot. 27, 3.

Taylor, H.C. 1969. A vegetation survey of the Cape of Good Hope Nature Reserve. Unpubl. M.Sc. thesis, Univ. of Cape Town.

Taylor, H.C. 1978. Phytogeography and ecology of Capensis. In M.J.A. Werger (Ed.), The Biogeography and ecology of Southern Africa. Junk, The Hague.

Theal, G.McC. 1882. Chronicles of Cape commanders. Cape Town.

Thunberg and Kotze, J.J. 1940. Some Langeberg forests. S. Afr. For. Assoc. 5.

Trigonometrical Survey Office 1962-1970. 1:50 000 Topographical Map Series. Government Printer Pretoria.

Tyson, P.D. 1964. Berg winds of South Africa. Weather, 19: 7-11.

van der Merwe, P. 1966. Die flora van Swartboschkloof, Stellenbosch en die herstel van die soorte na 'n brand. Annals. Univ. Stell. 41, Ser. A., No. 14.

van der Schiff, H.P. and Schoonrad, E. 1971. The Flora of the Marieskop Complex. Bothalia 10, 3 : 461-500.

van der Zel, D.W. and Kruger, F.J. 1975. The influence of total protection of Fynbos in Langrivier catchment, Jonkershoek on the total annual and late summer stream discharge. For. S. Afr. 16 : 13-18.

van Zinderren-Bakker, E.M. 1967. Upper pleistocene and holocene stratigraphy and ecology on the basis of vegetation changes in Sub-Saharan Africa. In Background to Evolution in Africa. Ed. Bishop, W.W. and Clark, J.D. Univ. of Chicago press.

van Zinderren-Bakker, E.M. 1969. Palaeoecology of Africa 4. Balkema, Cape Town.

van Zinderren-Bakker, Jr., E.M. 1973. Ecological investigations of forest communities in the Eastern Orange Feee State and the adjacent Natal Drakensberg. Vegetatio. 28(5-6) : 299-334.

van Zinderren-Bakker, E.M. 1978. Quarternary vegetation changes in Southern Africa. In M.J.A. Werger (Ed.) Biogeography and ecology of Southern Africa. Junk, The Hague.

von Breitenbach, F. 1965. The Indigenous Trees of Southern Africa (5 volumes). Government Printer, Pretoria.

von Breitenbach, F. 1972. Indigenous Forests of the Southern Cape. J. Bot. Soc. S. Afr. 58 : 17-47.

von Breitenbach, F. 1974. Southern Cape Forests and Trees. Government Printer, Pretoria.

Walter, H. and Leith, H. 1960. Klimadiagramm - Weltatlas, Fischer, Jena.

Weather Bureau. 1954. Climate of South Africa. Part I. Climate Statistics. Government Printer, Pretoria.

Weather Bureau. 1964. Climate of South Africa. Part 9. Average Monthly Rainfall. Government Printer, Pretoria.

Weather Bureau. 1975. Climate of South Africa. Part 12. Surface Winds. Government Printer, Pretoria.

Wellington, J.H. 1955. Southern Africa, a geographical study. Vol. 1 : Physical geography. University Press, Cambridge.

Werger, M.J.A. 1972. Species - area relationships and plot size : with some examples from South African vegetation. Bothalia 10 : 583-594.

Werger, M.J.A. 1973a. Phytosociology of the Upper Orange River Valley, South Africa. V and R, Pretoria.

Werger, M.J.A. 1973b. An account of the plant communities of Tussen die Riviere Game Farm, O.F.S. Bothalia 11 : 165-176.

Werger, M.J.A. 1974. On concepts and techniques applied in the Zurich-Montpellier method of vegetation survey. Bothalia 11 : 309-323.

Werger, M.J.A. 1978. Biogeographical division of Southern Africa. In M.J.A. Werger (Ed.) Biogeography and ecology of Southern Africa. Dr. W. Junk, The Hague.

Werger, M.J.A., Kruger, F.J. and Taylor, H.C. 1972. A phytosociological study of the Cape fynbos and other vegetation at Jonkershoek, Stellenbosch. Bothalia 10 : 599-614.

Westhoff, V. 1967. Problems and the use of structure in the classification of vegetation. Acta. Bot. Neerl. 15 : 495-511.

Westhoff, V. and van der Maarel, E. 1973. The Braun-Blanquet approach. In : R.H. Whittaker (Ed.) Ordination and classification of communities. Handbook of Vegetation Science 5 : 617-726. Junk, The Hague.

White, F. 1978. The Afromontane Region. In : M.J.A. Werger (Ed.) Biogeography and ecology of Southern Africa. Junk, The Hague.

Whittaker, R.H. 1956. Vegetation of the Great Smoky Mountains. Ecol. Mono. 26 : 1-80.

Whittaker, R.H. 1960. Classification of natural communities. Biol. re. 42 : 207-264.

Whittaker, R.H. 1970. Communities and Ecosystems. Macmillan Co., London.

Wicht, C.L. 1945. Preservation of the vegetation of the South-western Cape. Spec. publ. Roy. Soc. S. Afr. Cape Town.

Worral, G.A. 1960. Patchiness in vegetation in the Northern Sudan. J. Ecol. 48 : 107-115.

APPENDIX 1 : SPECIES LIST

The list of species below encompasses all plants referred to in the text. Families and genera of Pteridophyta are arranged according to Schelpe (1969) and Spermatophyta according to Dyer (1975 and 1976).

PTERIDOPHYTA

LYCOPODIACEAE

Lycopodium gnidioides L.f

OSMUNDACEAE

Todea barbara (L.) Moore

GLEICHENIACEAE

Gleichenia polypodioides Smith (L) Sm

HYMENOPHYLLACEAE

Humenophyllum capense Schrad.

H. tunbridgense (L.) Smith

CYATHEACEAE

Alsophilla capensis (L.f.) J. Smith

DENNSTAEDTIACEAE

Histiopteris incisa Thunb. J.Sm.

ADIANTACEAE

Pteris dentata (Forsk.)

Cheilanthes hirta Sw.

Dryopteris (Adanson) Sp.

Pellaea viridis (Forsk.) Prantl.

POLYPODIACEAE

Pleopeltis lanceolatum (L)

ASPLENIACEAE

Asplenium erectum Bory ex Willd.

A. aethiopicum (Burm.) Becherer

A. lunulatum Sw.

A. adiantum-nigrum L.

A. rutaefolium (Berg.) Kunze

THELYPTERIDACEAE

Thelypteris bergiana (Schlecht.)

LOMARIOPSIDACEAE

Elaphoglossum conforme (Sw.) J.Sm.

ASPIDIAECEAE

Polystichum zambesiacum Schelpe "P. ammifolium"

Ruhmora adiantiformis (Forst.) Ching.

BLECHNACEAE

Blechnum attenuatum (Sw.)

B. australe L.

B. capense (L.) Schlecht

B. punctualatum Sw.

B. tabulare (Thunb.) Kuhn

SPERMATOPHYTA

PODOCARPACEAE

<u>Podocarpus</u> <u>elongatus</u> (Ait.) L'Herit ex Pers

<u>P.</u> <u>falcatus</u> (Thunb.) R.Br. ex Mirb

<u>P.</u> <u>latifolium</u> (Thunb.) R.Br. ex Mirb

CUPRESSACEAE

<u>Widdringtonia</u> <u>nodiflora</u> (L.) Powrie

POACEAE

<u>Schoenoxiphium</u> <u>lanceum</u> Kuk

<u>Stipa</u> <u>dregena</u> Steud

<u>Oplismenus</u> <u>hirtellus</u> (L.) Beauv.

CYPERACEAE

<u>Ficinia</u> (Schrad.) spp.

<u>Carex</u> <u>aethiopica</u> Schkuhr

ARACEAE

<u>Zandetischia</u> <u>aethiopica</u> Spreng

JUNCACEAE

<u>Juncus</u> <u>lomatophyllus</u> L.

RESTIONACEAE

<u>Elegia</u> (L.) spp.

LILIACEAE

<u>Aloe</u> <u>arborescens</u> Miller

<u>A.</u> <u>ferox</u> Miller

<u>Asparagus</u> <u>aethiopicus</u> L.

<u>A.</u> <u>asparagoides</u> Wight.

PHOTO 9: The edge of short dry forest. Shrubs in the foreground are Carissa bispinosa and Grewia occidentalis. The trees in the background are mainly Cassine peragua.

PHOTO 10: Medium moist forest with a low ground cover. Common tree species include Olinia ventosa, Rapanea melanophloeos, Apodytes dimidiata, and Olea capensis subsp. capensis.

A. scandens Thunb.

A. setaceus (Kwnth.) Jessop

A. striatus (Linn. f.) Thunb.

A. thunbergianus Schult

Chlorophytum spp. Kerr.

IRIDACEAE

Dietes vegeta (Mill) N.E. Br.

Aristea sp. Ait

ORCHIDACEAE

Ploystachya (Hook) spp.

PIPERACEAE

Piper capense L.f.

Peperomia tetraphylla (G. Forster) Hook and Arn.

P. retusa A. Dietr.

SALICACEAE

Salix mucronata Thunb.

MYRICACEAE

Myrica serrata Lam.

ULMACEAE

Celtis africana N.L. Burm.

MORACEAE

Ficus capensis Thunb.

URTICACEAE

Drougetia ambiqua L.

D. thunbergii N.E. Br.

PROTEACEAE

Brabejum stellatifolium L.

Leucadendron argenteum (L.) R. Br.

PORTULACACEAE

Portulacaria afra. Jacq.

RANUNCULACEAE

Knowltonia capensis Huth.

LAURACEAE

Ocotea bullata (Burch.)

Cryptocarya angustifolia E. Meyer

PITTOSPORACEAE

Pittosporum viridiflorum Sims.

CUNONIACEAE

Platylophus trifoliatus (Thunb.) D.Don.

HAMAMELIDACEAE

Trichocladus crinitus (Thunb.)

ROSACEAE

Rubus pinnatus Willd.

LEGUMINOSAE

Virgilia oroboides (Berg.) Salter

Psoralea pinnata L.

Acacia karoo Hayne

OXALIDACEAE

Oxalis (L.) spp.

RUTACEAE

Calodendron capense (L.f.) Thunb.

POLYGALACEAE

Polygala myrtifolia L.

EUPHORBIACEAE

Lachnostylis hirta (L.f.) Muell. Arg.

Clutia pulchella L.

ANACARDIACEAE

Laurophyllous capensis Thunb.

Rhus lucida L.

R. lancea L.f.

R. tomentosa L.

R. glauca Thunb.

AQUIFOLIACEAE

Ilex mitis (L.) Radlk.

CELASTRACEAE

Maytenus accuminata (L.f.) Loes

M. heterophylla (Ecklon and Zeyer) N.K.B.Robson

M. oleoides (Lam.) Loes

M. undata (Thunb.) Blakflock

Putterlickia pyracantha (L.) Szyszyl.

Pterocelastrus rostratus (Thunb.) Walp

P. tricuspidatus (Lam.) Sonder

Cassine peragua L.

C. aethiopica Thunb.

C. papillosa (Hochst.) Kuntze

Maurocenia frangularia (L.) Miller

Hartogia schinoides C.A. Smith

ICACINACEAE

Cassinopsis ilicifolia (Hochst.) Kuntze

Apodytes dimidiata E. Meyer ex Arn.

Pyrenacantha scandens Planch.

BALSAMINACEAE

Impatiens capensis L.Bol.

RHAMNACEAE

Scutia myrtina (N.L.Burm.) Kurz

Rhamnus prinoides L'Herit

VITACEAE

Rhoicissus digitata (L.f.) Gulg and Brandt

R. tomentosa (Lam.) Wild and R.B. Drumm

TILIACEAE

Sparrmannia africana L.f.

Grewia occidentalis L.

G. robusta Burch

FLACOURTIACEAE

Kiggelaria africana L.

Scolopia mundii (Echlon and Zeyer) Warb

Trimeria grandifolia (Hochst.) Warb

OLINIACEAE

Olinia ventosa (L.) Cufod

APIACEAE

Heteromorpha arborescens (Sprengel) Cham. and Schlecht

MYRTACEAE

Metrosideros angustifolia (L.) Smith

ARALIACEAE

Cussonia spicata Thunb.

C. thyrsiflora Thunb.

CORNACEAE

Curtisia dentata (N.L.Burm.) C.A. Smith

ERICACEAE

Erica sp. (L)

MYRSINACEAE

Myrsine africana L.

Rapanea melanophloeos (L.) Mez

SAPOTACEAE

Sideroxylon inerme L.

EBENACEAE

Euclea undulata Thunb.

E. racemosa Murray

Diospyros glabra (L.) de Winter

D. whyteana (Hiern.) F. White

OLEACEAE

Linociera foveolata (E. Meyer) Knobl

Olea africana Miller

O. capensis (L.) subsp capensis

O. capensis (L.) supsp. marocarpa (C.H.Wright)

LOGANIACEAE

Nuxia floribunda Benth

Buddleja saligna Willd.

B. salviifolia (L.) Lam

APOCYNACEAE

Carissa bispinosa (L.) Desf. ex Brenan

Gonioma kamassi E. Meyer

ASCLEPIADACEAE

Secamone alpini Schultes

LAMIACEAE

Plectranthus fruticosus L'Herit

SOLANACEAE

Solanum giganteum Jacq

S. mauritianum Scop

SCROPHULIARACEAE

Nemesia petiolina Hiern.

SCROPHULARIACEAE

Halleria lucida L.

RUBIACEAE

Burchellia bubalina (L.f.) T.R.Sim

Rothmannia capensis Thunb.

Canthium mundianum Cham, and Schlecht

C. obovatum Klotzsch

C. ventosum L.S. Moore

CUCURBITACEAE

Melothria sp. L.

CAMPANULACEAE

Lobelia spp. L.

COMPOSITAE

Brachylaena nerrifolia (L.f.) R.Br.

Elytropappus rhinocerotis Less

Hippia pillosa Druce

Senecio deltiodes Less

Osmites spp. L.

Athanasia trifuricata L.

APPENDIX 2 : BIRD LIST

The following list of birds recorded in the various forest complexes is based on data from Winterbottom (pers. comm. 1977).

	JONKERS BERG	RIVERS DALE	HEIDEL BERG	SWELLEN DAM	RIVIER SONDER END	HOTTEN-TOTS HOLLAND	CAPE PENIN-SULA
African Goshawk				+		+	+
Red-breasted sparrowhawk						+	+
Grey wing francolin		+	+				
Crowned Guinea fowl							+
Rock pigeon						+	
Rameron pigeon		+	+		+	+	+
Red-eyed turtle dove	+	+	+		+	+	
Cape turtle dove						+	+
Laughing dove						+	+
Cinnamon dove	+	+	+	+	+	+	+
Red cheated cuckoo	+	+	+	+		+	+
Klaas's cuckoo						+	+
Green loerie	+						
Bush owl		+	+				+
Speckled mousebird						+	+
Redfaced mousebird					+		
Brown hooded kingfisher					+		
Greater honeyguide		+					
Cardinal woodpecker		+					
Olive woodpecker		+				+	
Black sawwing	+			+			+
Grey cuckoo shrike			+	+			
Fork tailed drongo	+			+			
Black headed oriole	+						
Cape bulbul						+	+

	JONKERSBERG	RIVERSDALE	HEIDELBERG	SWELLENDAM	RIVIER SONDEREND	HOTTENTOTS HOLLAND	CAPE PENINSULA
Terestial Bulbul	+	+	+				
Sombre Bulbul	+	+	+	+	+	+	+
Olive Thrush	+	+	+	+	+	+	+
Chorister Robin	+						
Cape Robin	+	+	+	+	+	+	+
Knysna Scrub warbler							+
Yellow throated warbler				+			
Barthroated apalis	+	+	+	+	+	+	+
Spotted flycatcher						+	
Cape batis	+	+	+	+	+	+	+
Blue mantled flycatcher		+	+				
Paradise flycatcher	+	+	+	+	+	+	+
Puffback shrike	+						
Boubou	+	+	+	+	+	+	+
Olive bush-shrike		+	+				
Redwinged starling	+	+	+	+	+	+	+
Malachite sunbird				+		+	
Orangebreasted sunbird			+			+	+
Greater double collared sunbird				+			
Black sunbird	+						
Cape white eye	+	+	+	+	+	+	+
Cape weaver						+	
Swee	+	+	+	+	+		
Cape siskin					+	+	+
Cape canary						+	+
Forest canary	+	+	+				
Bully canary						+	
Bluebilled firefinch		+	+				

APPENDIX 3

PHOTOGRAPHS

PHOTO 1: Low south-east cloud on the foothills of the Langeberg mountains. Precipitation in the form of mists is important to the forests.

PHOTO 2: A typical example of a forest patch at Orange Kloof, Table Mountain. Note the scrub below the road which could develop into forest if fires are precluded.

PHOTO 3: A general view of the edge of Grootvadersbos forest showing the absence of marginal forest vegetation and the encroachment of alien species. The invading tree in this case is *Acacia mearnsii*.

PHOTO 4: A huge yellowwood (*Podocarpus latifolius*) trunk left to rot in the forest after being felled and sawn. The steep terrain in this area probably made removal difficult.

PHOTO 5: A section of Grootvadersbos forest and the surrounding veld. The veld is burnt regularly to provide grazing precluding any spread of forest.

PHOTO 6: A wet forest stand showing the dense and tall(2m) _Alsophilla capensis_ understorey.