PHYTOSOCIOLOGY OF THE UPPER ORANGE RIVER VALLEY, SOUTH AFRICA

A SYNTAXONOMICAL AND SYNECOLOGICAL STUDY

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Frontispiece: Panorama drawn by R.J. GORDON when he discovered the Orange River at "De Fraaye Schoot" near the present Bethulie, probably on the 23rd December 1777.

I. INTRODUCTION

When the government of the Republic of South Africa in the early sixties decided to initiate a comprehensive water development scheme of its largest single water resource, the Orange River, this gave rise to a wide range of basic and applied scientific surveys of that area. The reasons for these surveys were threefold: (1) The huge capital investment on such a water scheme can only be justified economically on a long term basis. Basic to this is that the waterworks be protected, over a long period of time, against inefficiency caused by for example silting. Therefore, management reports of the catchment area should.be produced. (2) In order to enable effective long term planning of the management and use of the natural resources in the area it is necessary to know the state of the local ecosystems before a major change is instituted. (3) From an academic point of view it is of utmost interest to study alterations in an area that is due to undergo so much artificially induced change in a short period of time. All three arguments require studies of the initial area, that is before the changes are made.

This account reports on one of these surveys, namely an inventory of the plant communities of the Upper Orange River valley. The part of the survey that covers the riverine vegetation is included in topic 6 ORDS project 6.3 of the Orange River Workgroup and subproject 8.5 of the IBP PF (International Biological Programme, section Productivity of Freshwater).

An inventory of plant communities of a certain area, if done in a scientifically sound way, can serve as a basis for further basic scientific work of academic interest as well as for applied scientific work orientated towards management. Because of the deteriorated condition of the veld in the Upper Orange River catchment area at present, erosion is severe and therefore holds a serious threat to the economic and functional existence of the large waterworks presently under construction in that area. In order to stop this erosion a report on veld management is necessary. Therefore, a survey on the grazing potential, condition and erosion status of the veld is presently being undertaken in four catchment areas, together comprising the Orange River catchment area upstream of the Hendrik Verwoerd Dam. The veld is being mapped in floristical dominance types, subdivided according to condition and erosion status, at a scale of 1 : 50 000. Classifying a vegetational cover in dominance types is only of restricted value, however, and it was felt that a more scientifically based classification would be advantageous. The present survey was therefore undertaken to inventorize and describe the plant communities occurring in the area. To survey the complete Upper Orange River catchment area, however, would take too many years for the one surveyor that was available. So, the survey was restricted to the Upper Orange River valley. The interpretation of the word "valley" was taken in its widest sense and is defined later. It was thought that the plant communities found in the survey area should provide possibilities of extrapolating into a wide area of the Orange River catchment area, especially into the Highveld region, where other surveys are underway at present, and into the Karoo. Thus, this report should provide information on an extensive part of the central regions of the Republic of South Africa.

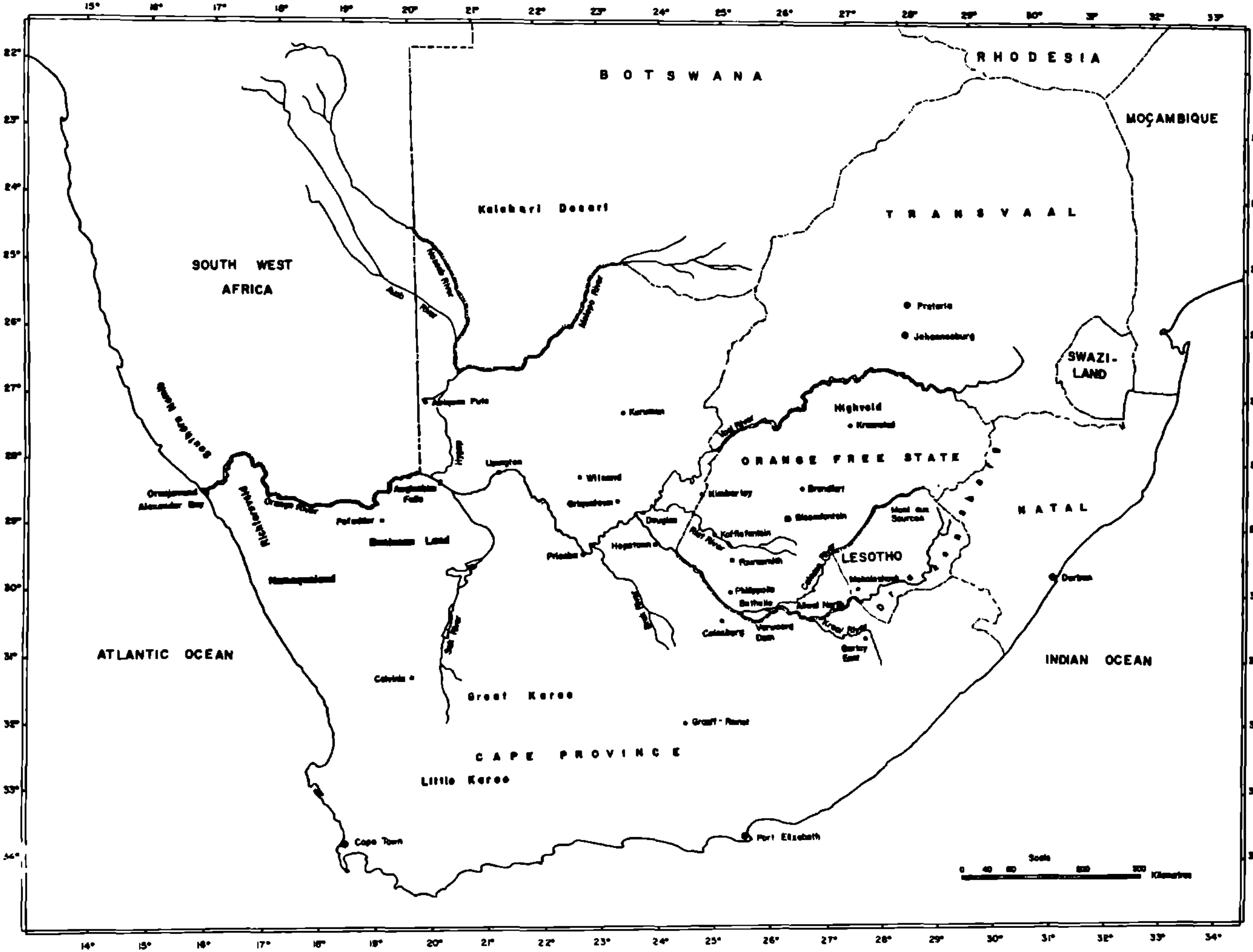


Fig. II.1 Map of southern Africa showing the position of the Orange River.

II. THE AREA

The longest river in Africa south of the Zambezi and the largest river in the Republic of South Africa is the Orange River. It is also the only river in southern Africa to rise on one edge of the African plateau and to flow to the opposite edge (WELLINGTON, 1955). From its source in the Drakensberg in Lesotho, where it is called Sinqu, down to its mouth in the Atlantic at Alexander Bay - Oranjemund, the distance along the longitudinal river profile is approximately 2 200 km. Its source at Mont aux Sources is at 3 300 m, thus giving an average gradient for the whole Orange River of 1,5 m per km. The Vaal River, the Orange River's greatest tributary, joins the Orange River about 16 km downstream from Douglas and is longer than the Orange River upstream of the confluence. Taking the Vaal headwater as the main stream, the river measures 2 500 km along its longitudinal profile. However, the branch that rises in Lesotho has always been considered to be the main stream (fig. II.1).

The Orange River basin covers 650 000 km^2 and is the largest river basin south of the Zambezi, that has an outlet to the sea. The only larger one is the Kalahari basin, that measures 1 290 000 km^2, but nearly half of it is areic and the remaining part endoreic. Formerly part of the Kalahari basin, the Molopo-Nossob system, drained into the Orange River. More than 1000 years ago this drainage was blocked by wind-blown sand and the rare flood-waters now drain into Abiquas Puts. With this typical feature of blocking river courses by wind-blown sand, this system can be regarded as being part of the endoreic half of the Kalahari basin (WELLINGTON, 1955, 1958). MOOLMAN (1946) considered the Molopo-Nossob system to belong to the Orange River basin.

On its way from its origin in the humid Drakensberg, the main watershed of South Africa, through the semi-arid and arid areas down to the Atlantic, the Orange River traverses nearly the whole succession of geological formations found in southern Africa, from the relatively young basalts, sandstones, shales and tillites of the Karoo System to the granites, lavas and quartzites of the Archaean complex. On its general east-west course it also flows through a diversity of soil types (from the black clay soils in the Drakensberg and the prairie soils of the Highveld to the Kalahari sands and the desert soils of Bushmanland and Namaqualand) and a series of veld types (from the alpine and Highveld grasslands, the open shrublands of the Karoo to the semi-desert and succulent vegetation types of the Namaqualand Broken Veld, the Succulent Karoo in the Richtersveld, and the desert vegetation of the southern Namib near Alexander Bay). Taking the total diversity of the physical environment into account, the Orange River is usually divided into three physiographic sections (WELLINGTON, 1933): the Upper Orange River from its origin at Mont aux Sources down to its confluence with the Vaal River; the Middle Orange River from the Orange-Vaal confluence down to Aughrabies Falls and the Lower Orange River from Aughrabies Falls down to the mouth in the Atlantic Ocean. This report deals with the ecology and plant communities of the Upper Orange River only (fig. II.2). Therefore, the physical environment and human history of that part will now be described in more detail.

II.1 TOPOGRAPHY AND HYDROLOGY

When the Orange River at the confluence with the Telle River, near Palmietfontein, becomes the border between Lesotho and the Republic of South Africa, its altitude has dropped from about 3 300 m at its origin at Mont aux Sources to 1 398 m. Twenty six km further downstream is the confluence of the Orange River with the Kornetspruit, which forms the border between Lesotho and the Republic of South Africa to the north, just as the Telle River does to the south. At this point the height of the riverbed is 1 385 m, which means an average gradient of 0,50 m/km over the stretch where the Orange forms the international border. Here the Orange River actually enters South Africa, forming the border between the Orange Free State and the Cape Province. In this part of the Cape Province the Bantustan Herschel is situated, of which the Orange River forms the northern border down to the point where the Wilgespruit enters the Orange, 146 km downstream of the Orange-Telle confluence. Twenty four km downstream of the Orange-Kornetspruit confluence is the first roadbridge within the borders of the Republic of South Africa across the Orange River, Mayaputi bridge, connecting Sterkspruit with Zastron. The height of the riverbed here is 1 357 m, making an average gradient of 1,17 m/km over these 24 km of the river. Twenty km downstream of Mayaputi bridge the Orange River is joined by the small river Sterkspruit. Along the Sterkspruit,5 km upstream of the confluence,a village of the same name is located. At this confluence point the height of the riverbed has dropped to 1 345 m, resulting in an average gradient of 0,60 m/km from Mayaputi bridge to this point. At the Orange-Wilgespruit confluence the altitude is 1 311 m, which gives an average gradient of 0,45 m/km between Sterkspruit and Wilgespruit. The second bridge over the river is at the town of Aliwal North, the main centre for a large area, situated 139 km downstream of the Orange-Kornetspruit confluence. Just upstream of Aliwal North the Orange is joined by the Kraai River, the main drainage channel of the north eastern Cape. At Aliwal North the height of the riverbed is 1 296 m, which means an average gradient between Aliwal North and the Wilgespruit entry point of 0,79 m/km, between Aliwal North and the Orange-Kornetspruit confluence of 0,64 m/km and between Aliwal North and the Orange-Telle confluence of 0,61 m/km. At Goedemoed, a small settlement 38 km downstream of Aliwal North, the water of the Orange River is used to irrigate the fields of the local prison farm. Here the height of the riverbed is 1 277 m, which gives an average gradient between Aliwal North and Goedemoed of 0,50 m/km. Seventeen km further downstream the Orange River reaches the Tussen die Riviere Game Farm, forming more or less its southern boundary for the next 45 km. When the Hendrik Verwoerd Dam is filled to total capacity in its initial stage of development, the water reaches this Game Farm. Just before the Upper Orange River leaves Tussen die Riviere Game Farm, 89 km downstream of Aliwal North, it is joined by its largest tributary, the Caledon River. This tributary is a perennial stream, that drains western Lesotho and the eastern Orange Free State. At the junction the altitude of the Orange River bed is 1 243 m. Thus the average gradient between this junction and Goedemoed is 0,67 m/km and between this junction and the Orange-Kornetspruit confluence 0,62 m/km. Ten km further downstream the combined waters of the Orange and Caledon Rivers reach Bethulie, at an altitude of 1 241 m at the bridge, resulting in an average gradient of 0,20 m/km between here and the Orange-Caledon confluence. Forty one km downstream of Bethulie on the Cape side lie the villages of Venterstad and Oviston at the entrance of the nearly 83 km long Orange-Fish tunnel, bringing the water of the Orange River to the Fish River and from there through a second tunnel to the Sundays River (JORDAAN, 1962-63). In this way part of the water of the Orange River reaches the Indian Ocean. Eighty km downstream of Bethulie, 318 km downstream of the Orange-Kornetspruit confluence, at Oranjekrag, is the wall of the Hendrik Verwoerd Dam.

The Hendrik Verwoerd Dam is intended to be the main storage dam to regulate the flow of the Orange River and provide sufficient storage capacity for silt deposits. It is planned to raise the dam wall in a number of successive stages over 120 years, in order to maintain enough storage capacity against silt deposits. The present dam wall is 85 m high, 905 m long and the dam has a gross storage capacity of 5 952 million m^3. When full, the Hendrik Verwoerd Dam at its present dam wall level has a surface area of approximately 700 km^2 (JORDAAN, 1962-63; 1964-65; KRIEL, 1971-72).

At the foot of the wall the altitude measures 1 193 m. This gives an average gradient of the river floor of 0,23 m/km over the part from Bethulie to Oranjekrag, and of 0,60 m/km over the part between Oranjekrag and the Orange-Kornetspruit confluence. The village of Norvalspont is 5 km downstream of the wall. The distance from the wall to the roadbridge over the Orange River, that connects Colesberg with Philippolis, is 38 km. At this bridge the height of the riverbed is 1 183 m, giving an average gradient of 0,26 m/km between here and the Hendrik Verwoerd Dam wall. The proposed P.K. le Roux Dam wall, that is under construction near Petrusville, 121 km downstream of Oranjekrag, will, when full, push the water back to the farm Skurwekop 60 km downstream of Oranjekrag, 22 km downstream of the roadbridge near Colesberg. This P.K. le Roux Dam lake will be narrow and deep. At the foot of P.K. le Roux Dam wall the altitude is 1 098 m, which gives an average gradient of 1,02 m/km over the part from the roadbridge near Colesberg to the wall site, of 0,79 m/km over the part between the P.K. le Roux and Hendrik Verwoerd Dam wall sites and of 0,65 m/km over the part between the P.K. le Roux Dam wall site and the Orange-Kornetspruit confluence

The P.K. le Roux Dam wall will initially be 101 m high and 792 m long, resulting in a gross storage capacity of 3 185 million m^3 (KRIEL, 1971-72). From here long canals will branch out to irrigate an area on the left bank, which was originally planned to extend as far as Sakrivier in the central Karoo and Witsand in the Northern Cape at a distance of 900 km from P.K. le Roux Dam (JORDAAN, 1962-63). Later studies recommended, however, to irrigate in the initial phase only the area between P.K. le Roux Dam and Hopetown (KRIEL, 1971-72). The right bank canal will supply water to the Riet River valley, at a point 27 km downstream of Koffiefontein and to the area near the Vaal-Riet confluence. With this water nearly 120 000 ha can be irrigated. The inlet of these canals at the dam wall will be at such a level, that of the gross storage capacity 992 million m^3 will still be below the invert level, in order to provide for storing of silt which passes the main dam at Oranjekrag, for the coming 200 years. The construction provides for an eventual raising of the dam wall, that would dam up the water to the foot of the Hendrik Verwoerd Dam (JORDAAN, 1962-63; KRIEL, 1971-72).

Fifty km downstream of P.K. le Roux Dam, near the new settlement Orania, a roadbridge

crosses the Orange River. Here the altitude of the riverbed is 1 083 m and the average gradient between Orania and P.K. le Roux Dam is 0,30 m/km. Ninety six km downstream of P.K. le Roux Dam is the roadbridge near Hopetown, where the altitude of the riverbed is 1 061 m. This results in an average gradient of 0,48 m/km between here and Orania. From Hopetown to the proposed site of the Torquay Dam wall is a distance of 51 km. The altitude of the riverbed at Torquay is 1 000 m, resulting in an average gradient of 1,20 m/km between Torquay and Hopetown roadbridge, of 0,67 m/km between Torquay and P.K. le Roux Dam and of 0,66 m/km between Torquay and the Orange-Kornetspruit confluence.
The Torquay Dam will dam up water of the Orange River until close to the old road bridge just downstream of Hopetown. The Torquay Dam is planned to serve irrigable land on the right bank of the Orange between Torquay and Douglas, as well as land along the Middle Orange River and Brak River towards Prieska. The dam is also planned to serve for the generation of hydro-electric power. Preliminarily the dam wall is planned to be 70 m high, giving a storage capacity of 392 million m^3, of which about 131 million m^3 will be below the lowest outlet level (JORDAAN, 1962-63).

The distance from the Torquay Dam site to the Orange-Vaal confluence at Mazelsfontein is 44 km. At the Orange-Vaal confluence the altitude of the riverbed is 974 m, giving an average gradient of 0,59 m/km between the Torquay Dam site and this confluence.

From the Orange-Kornetspruit confluence, where the Orange River actually enters South Africa, to the Orange-Vaal confluence at Mazelsfontein the distance along the longitudinal profile of the river measures 630 km. This brings the average gradient of the Upper Orange river within the Republic of South Africa to 0,65 m/km.

Table II.1 summarizes the gradient data of the Upper Orange River within the Republic of South Africa.

At the Orange-Vaal confluence the river enters a new physiographic region, known as the middle course of the Orange River, and leaves the present study area.

The direction of the Upper Orange River is WSW from the Orange-Kornetspruit confluence to Aliwal North, WNW from Aliwal North to Tussen die Riviere Game Farm, from Tussen die Riviere Game Farm to Venterstad again WSW and from here to the Orange-Vaal confluence the river takes a NW course.

The only perennial tributary of the Upper Orange River is the Caledon River. According to WELLINGTON (1955), who bases his information on data from the period 1919-1935, the average number of days of flow of the Caledon during the year is 359. The mean annual flow of the Caledon during the above-mentioned period was $1,1.10^9$ m^3, the minimum $2,5.10^8$ m^3 and the maximum $3,3.10^9$ m^3. March, January and November in that order were the months with the highest flows, and June the month with the lowest. Flow was measured at a gauge near Wepener, where water collects from a catchment area of 13 300 km^2.

During the period 1913 to 1945 data were collected at a gauge located at the railway bridge at Orange River Station, 15 km upstream of Hopetown. The catchment of the river above the gauge measures 95 300 km^2. The mean annual flow here was $7,6.10^9$ m^3, with a minimum of $1,4.10^9$ m^3 and a maximum of $19,4.10^9$ m^3. The peak flow was during March, followed by January and February. The lowest flow occurred during August. The mean number of days of flow were 364 days annually (WELLINGTON, 1955).

TABLE II.1 UPPER ORANGE RIVER : DISTANCES AND GRADIENTS

Locality	Distance from Orange-Kornetspruit confluence in km	Altitude of riverbed in m above sea level	Gradient between successive localities in m/km
Orange-Telle confluence	-26	1398	-
Orange-Kornetspruit confluence	0	1385	0,50
Mayaputi bridge	24	1357	1,17
Orange-Sterkspruit confluence	44	1345	0,60
Orange-Wilgespruit confluence	120	1311	0,45
Aliwal North	139	1296	0,79
Goedemoed	177	1277	0,50
Orange-Caledon confluence	228	1243	0,67
Bethulie bridge	238	1211	0,20
Foot of Hendrik Verwoerd Dam wall	318	1193	0,23
Roadbridge Colesberg-Philippolis	356	1183	0,26
Foot of P.K. le Roux Dam wall	439	1098	1,02
Orania	489	1083	0,30
Roadbridge Hopetown	535	1061	0,48
Foot of Torquay Dam wall	586	1000	1,20
Orange-Vaal confluence	630	974	0,59

By means of sampling over long periods, the silt load of the Orange River at Bethulie was determined as 0,80% of the run-off; at Aliwal North this figure was 0,56%. The Caledon yielded 22,3% of the mean annual flow at Hendrik Verwoerd Dam and 23% of the silt load there. Of these 22,3% of the mean annual flow 10,5% came from Lesotho and the remaining 11,8% from the area within the Republic of South Africa. The Kraai River contributed 12,5% of the water and 22,2% of the silt load. The remainder of the catchment between Lesotho and the Caledon contributed 10,1% of the flow and 23,9% of the silt load (JORDAAN, 1962-63; Commission of enquiry, 1970).

The run-off of the Orange River downstream of Bethulie measured as a percentage of the average rainfall over the catchment area was 1,6%; the figure for the Orange and Caledon Rivers upstream of Bethulie was 14,0% (Commission of enquiry, 1970).

Although the Orange River is a perennial stream with flow peaks towards the end of the rainy season and flow minima during mid-winter, the water flow is not at all regular. Destructive floods, which inundate the banks and bring down much silt and sand, are not rare. Exceptional floods have been recorded at Hopetown where in February 1874 a flood of more than 11 000 m^3/sec occurred and on 24th March 1925 a flood of about 9 000 m^3/sec was registered (JORDAAN, 1962-63). In 1967 a discharge of 10 500 m^3/sec was recorded at Bethulie (Commission of enquiry, 1970). With the present storage capacity of the Hendrik

Verwoerd Dam the frequency of these floods will be reduced by 50%, and will be further reduced when the dam wall is raised in the future. Obviously this will have its impact on the riverine communities downstream of Goedemoed. Possibly there will also be a slight change in the air humidity in the immediate neighbourhood of the large water-bodies, since the mean annual evaporation for the Hendrik Verwoerd and P.K. le Roux Dams together is estimated at 512 million m^3 (KRIEL, 1971-72).

II.2 CLIMATE

The entire area of the Upper Orange River is under the influence of a summer rainfall climate, although there are significant differences along the east-west gradient. According to KENDREW (1961) the weather is dominated by subtropical anticyclonic high pressure systems which, in winter, are centered at about latitude 28° S and, in summer, at about 33° S. Therefore, the winters are calm and almost rainless and are characterized by clear skies and light winds, mainly in the westerly quarter. Frosts occur regularly, particularly from May to September. In particular the area around Sterkspruit may be covered with snow for some days during the winter season, when outbreaks of cold humid air from the south sweep across the Karoo and Highveld. In summer the land is heated by the sun, which is nearly overhead, causing the pressure to fall. Moist maritime tropical air from the Indian Ocean is drawn into the continent, bringing clouds and rain from the north. This does not mean, however, that the skies are usually cloudy during summer. On the contrary, skies are usually clear, causing high diurnal ranges in temperature, and the precipitation comes mainly from violent thunderstorms. Rainfall is highest in the higher lying areas in the east and decreases rapidly along the westward course of the Upper Orange River. Most of the area can be regarded as semi-arid (JACKSON, 1951; KENDREW, 1961).

Detailed climate statistics are available from eleven stations along or near the Upper Orange River (Weather Bureau, 1954, 1965b, 1967a, a, 1968, 1970, 1971). Stations situated at the Orange River are Aliwal North, Bethulie, Oviston, Hendrik Verwoerd Dam, P.K. le Roux Dam and Hopetown, whereas Mohaleshoek, Venterstad, Fauresmith, Andriesfontein and Griquatown are located up to about 75 km from the Orange River. Statistics from these eleven stations have been used to draw up climatic diagrams as proposed by WALTER & LIETH (1960) (fig. II.3). Venterstad, Oviston, Hendrik Verwoerd Dam and P.K. le Roux Dam have records over only a short period of time. Venterstad is situated near Oviston but further away from the river. The altitudes of all weather stations have been obtained from the publications of the Weather Bureau. These values may differ occasionally from those of the 1 : 50 000 topographical maps.

A detailed description of the climate of part of the area with special regard to agricultural purposes is given by WITHMORE (1950a, b, c).

II.2.1 Cloudiness

Cloud cover statistics are available from only four stations near the Upper Orange River, namely Aliwal North, Bethulie, Fauresmith and Andriesfontein (Weather Bureau, 1954). Cloudiness is rated on a 10-point scale and, except at Andriesfontein, were ascertained twice daily, namely at 0800 and 1400 hrs S.A.S.T. Table II.2 summarizes these figures.

TABLE II.2 CLOUD COVER

Station	Aliwal North		Bethulie		Fauresmith		Andriesfontein	
SL	30° 41'		30° 30'		29° 46'		30° 57'	
EL	26° 43'		25° 58'		25° 19		24° 36'	
Altitude (m)	1332		1274		1382		1359	
Period (years)	15	6	20	13	20	18	18	-
At (S.A.S.T.)	0800	1400	0800	1400	0800	1400	0800	-
January	2,4	4,2	2,3	4,6	3,1	5,0	2,8	-
February	2,8	4,5	2,9	5,0	3,3	5,2	2,7	-
March	2,6	4,0	3,3	4,8	3,5	5,2	3,0	-
April	2,7	3,6	3,1	4,2	3,3	4,2	3,4	-
May	2,4	3,0	2,8	3,5	3,0	3,6	3,7	-
June	2,1	2,2	2,0	2,5	2,4	2,8	2,8	-
July	1,8	1,6	2,3	2,1	2,3	2,3	2,9	-
August	1,9	2,5	1,9	2,3	2,1	2,1	2,4	-
September	2,3	3,5	2,5	3,3	2,5	3,1	3,0	-
October	3,2	4,2	3,5	4,3	3,7	4,4	3,8	-
November	2,9	4,5	3,2	4,7	3,4	4,6	3,5	-
December	2,5	4,3	2,4	4,5	2,7	4,8	2,4	-
Year	2,5	3,5	2,7	3,8	2,9	4,0	3,0	-

Although it may be premature to draw conclusions about cloudiness on the basis of so little data, some persistent features can be mentioned. In the Upper Orange River area, the cloudiness is far higher in the afternoon than in the morning (table II.2). Further there seems to be a slight increase in cloudiness from east to west. The most interesting feature, that can be discerned from these figures is the double period in cloudiness during the year. The 0800 hrs S.A.S.T. figures show this double period particularly clearly. There is generally a first and absolute maximum in February-March and a second minor maximum during October-November. The maximum during February-March coincides with the maximum in precipitation, as will be shown in Chapter II.2.7. The double period in cloudiness is related to the seasonal change in general circulation of the atmosphere. The high pressure belt, that during summer is located above the southern Karoo area shifts north toward the Highveld region, where it is located during winter. As the high pressure belt passes over, in February-March and October-November, it brings an increase in cloudiness.

II.2.2 Sunshine

Statistics on duration of sunshine are available from only two stations located near the Upper Orange River, Aliwal North and Fauresmith (Weather Bureau, 1965a) (table II.3). Generalized maps of the Weather Bureau (1950) combined with figures from these two stations show, that the Upper Orange River area falls completely within a zone where the average annual duration of bright sunshine is between 70% and 80% of the possible sunshine. In January the whole area also falls into this zone, whereas in July the whole area falls into a zone of 80% to 90% of the possible sunshine. It is not surprising that the period of maximum sunshine coincides with the period of minimum cloudiness.

TABLE II.3 AVERAGE MONTHLY AND ANNUAL SUNSHINE

ALIWAL NORTH, 30^{o} 41' S, 26^{o} 43' E, altitude 1 316 m, period of observation: 5 years.

Month	Mean daily hours	% of possible duration	Number of days with % of possible sunshine				
			nil	1-10	11-49	50-89	90-100
January	10,4	75	0,0	0,4	3,0	19,2	8,4
February	9,9	75	0,4	0,6	3,6	11,6	12,0
March	8,9	72	1,0	1,0	4,0	13,2	11,8
April	8,7	77	0,4	0,8	4,4	8,8	15,6
May	7,9	74	0,4	1,6	4,8	10,4	13,8
June	8,3	81	0,8	0,2	2,2	10,4	16,4
July	8,5	82	0,2	0,2	3,6	9,0	18,0
August	9,5	86	0,4	0,2	2,4	6,4	21,6
September	9,7	81	0,4	0,2	2,8	9,4	17,2
October	9,9	77	0,6	0,8	3,8	10,4	15,4
November	10,6	77	0,0	0,2	4,2	11,4	14,2
December	10,3	73	0,4	0,8	5,2	12,0	12,6
Year	9,4	78	5,0	7,0	44,0	132,2	177,0

FAURESMITH, 29^{o} 46' S, 25^{o} 19' E, altitude 1 382 m, period of observation: 3 years.

January	10,2	73	0,3	0,3	4,0	15,0	11,4
February	10,0	76	0,3	1,3	2,0	11,0	13,6
March	8,9	72	0,3	0,4	3,4	18,7	8,2
April	8,3	73	0,7	0,0	4,0	15,6	9,7
May	7,6	72	0,7	0,7	4,7	16,6	8,3
June	8,4	82	0,3	0,3	1,7	25,3	2,4
July	8,3	80	0,3	0,7	2,3	17,7	10,0
August	9,7	87	0,3	0,0	0,3	9,4	21,0
September	9,6	81	0,3	0,3	1,3	19,7	8,4
October	9,9	77	0,3	0,3	2,7	17,9	9,8
November	10,2	75	0,0	0,7	3,3	14,7	11,3
December	10,4	74	0,0	0,3	3,0	18,0	9,7
Year	9,3	77	3,8	5,3	32,7	199,6	123,8

The figures in table II.3 show also a double period, although less obvious than those of the cloudiness records. The double period agrees inversely with the periodicity of cloudiness. It is interesting to note, however, that the driest month (June) (see

Chapter II.2.7) is not the month with the highest amount of sunshine. Also from the cloudiness figures (table II.2) one can see, that although June is the driest month, the cloudiness reaches its minimum during August or July, thus giving the maximum sunshine during this time of the year. March, being the wettest month, shows the lowest amount of sunshine and a high cloud cover. But since this relatively low percentage of sunshine is still 72% for both Aliwal North and Fauresmith at the time of maximum precipitation, and since Aliwal North and Fauresmith during March still record 25 and 27,9 days with more than 50% of the possible sunshine respectively, this indicates that the rainfall in the Upper Orange River area loses much of its effectiveness.

II.2.3 Temperature

Records of temperature have been kept by eleven stations along or near the Upper Orange River. The monthly averages of the mean daily temperature (half the sum of the daily maxima and minima) are expressed in fig. II.3. Experiments revealed that the thus calculated mean monthly temperatures do differ less than 1°C from values obtained from thermograms read off hourly, for the whole of South Africa (Weather Bureau, 1965a). The mean yearly temperature, the absolute highest temperature, the absolute lowest temperature, the average daily minimum for the coldest month, the average daily maximum for the warmest month, the annual average of the daily range in temperature, the months with an average daily minimum temperature lower than 0°C, the months with an absolute minimum lower than 0°C and the mean duration of the frost free period are also expressed in fig. II.3. Temperature is recorded at 1,20 m above the ground at every station. For Aliwal North, Bethulie and Fauresmith the mean monthly temperatures at 0800 and 1400 hrs S.A.S.T. and for Mohaleshoek and Andriesfontein only at 0800 hrs S.A.S.T. have been measured (Weather Bureau, 1954) and are listed in table II.4.

From fig. II.3 it can be seen that the mean monthly temperatures of all the stations show an almost regular sinusoidal pattern, with a maximum in January and a minimum in July. Only Hendrik Verwoerd Dam shows a minimum in June, but this can easily be as a result of the short period of observation.

Temperature is to a large extent dependent on topography (GEIGER, 1965). This is shown clearly by the values of P.K. le Roux Dam, a station situated in a narrow, deep valley, and by the values of Mohaleshoek, which has, probably due to its sheltered situation in the mountains, a relatively high mean July temperature, although the station lies at 1 600 m. The lowest mean July values are recorded at Andriesfontein and Fauresmith, both lying on the plateau. The stations along the Orange River streambed, Aliwal North, Bethulie, Oviston, Hendrik Verwoerd Dam, P.K. le Roux Dam and Hopetown, show a gradual increase in mean January temperatures down the river. This can be due to metereological causes and partly to decreasing altitudes of the stations in this sequence as well. P.K. le Roux Dam shows the highest temperatures, which is probably related to local topographical features. The differences in mean monthly and mean yearly temperatures between the eleven stations are not marked, although differences between the mean temperatures of the warmest month are larger than those between the values of the coldest month. Table II.4

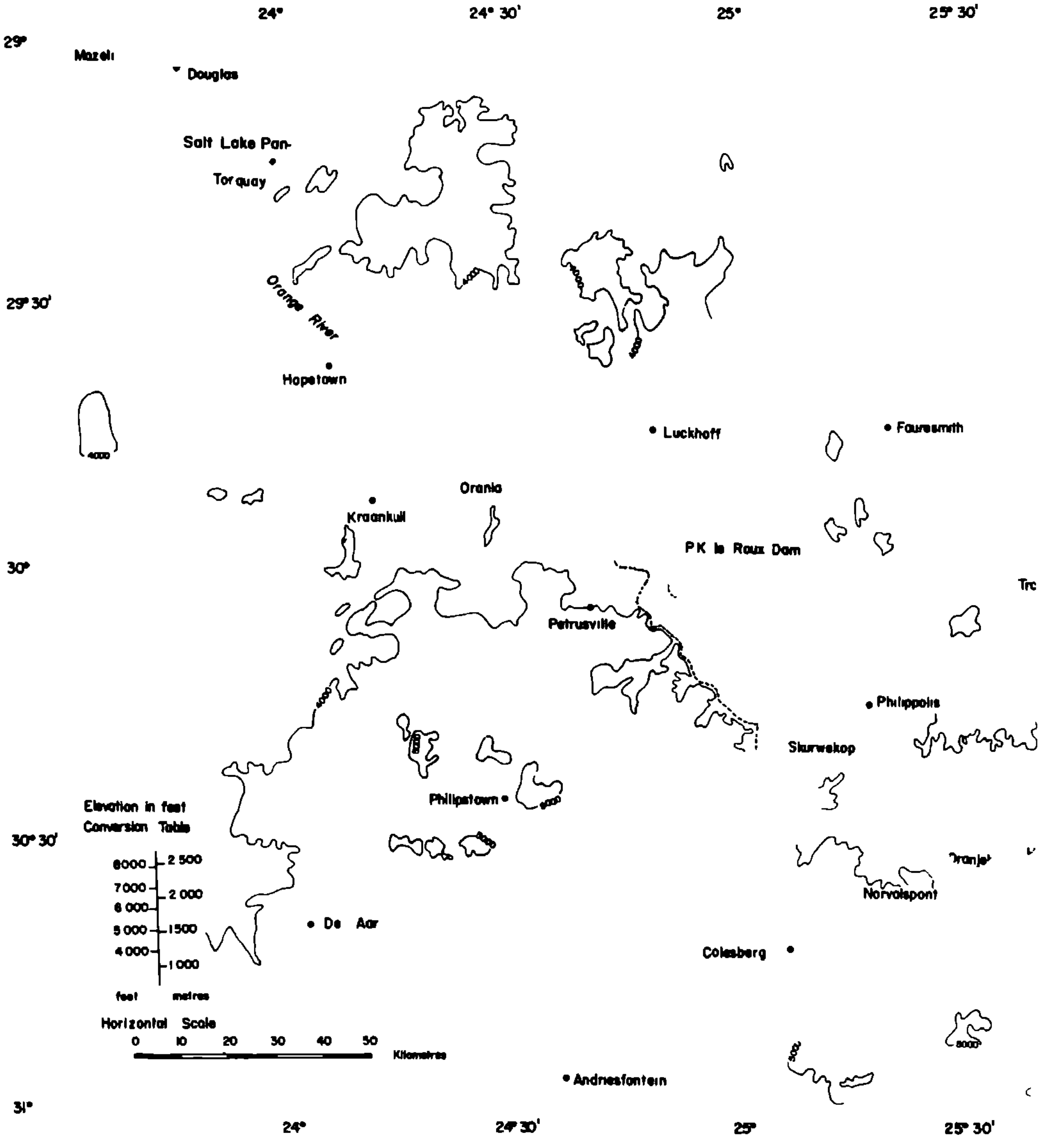
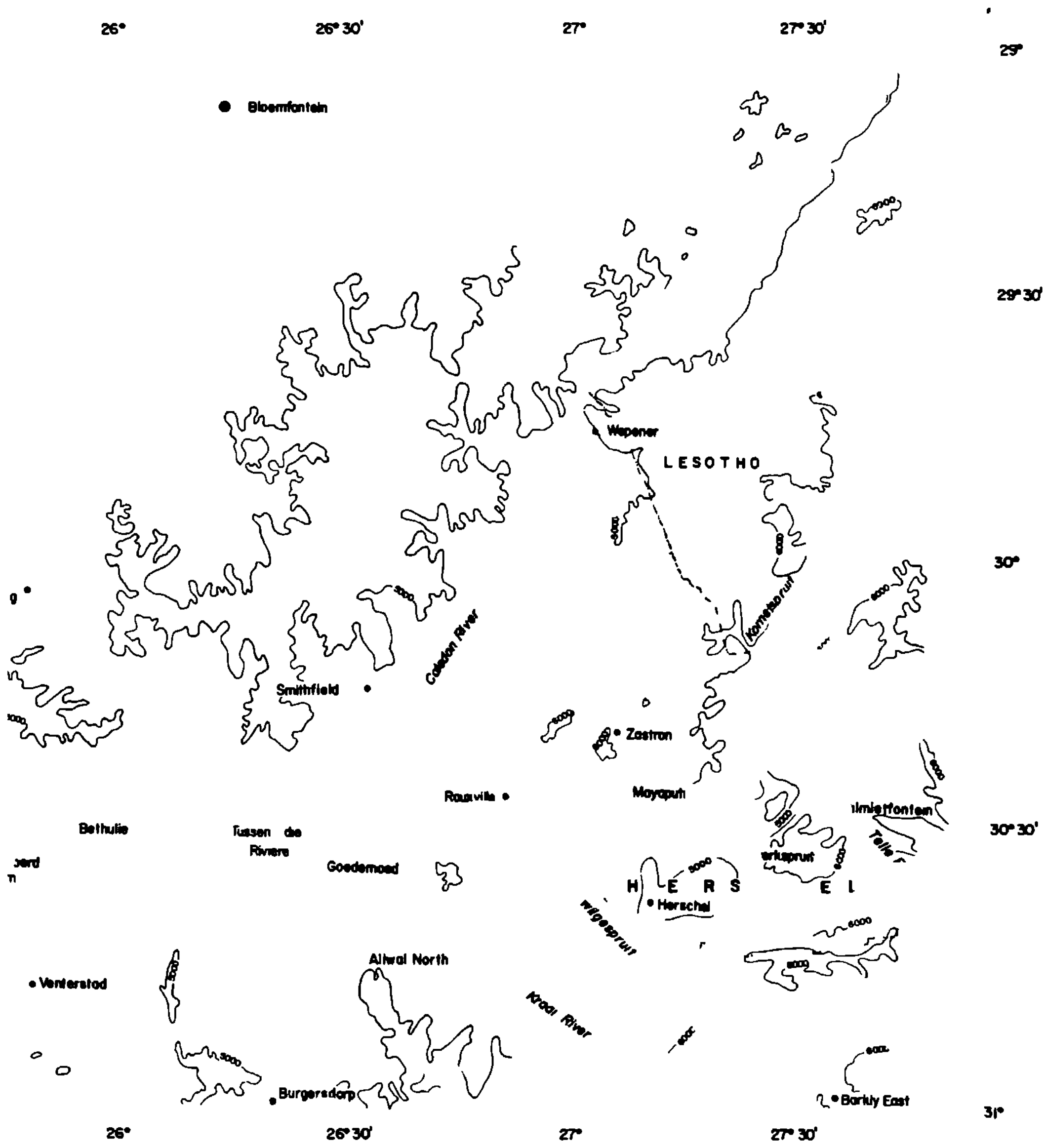


Fig. II.2 The Upper Orange River area topographically.


26°
26° 30'
27°
27° 30'
29°
29° 30'
30°
30° 30'
31°
Bloemfontein
Wepener
LESOTHO
Caledon River
Smithfield
Zastron
Kornetspruit
Rouxville
Mayaputi
Bethulie
Tussen die Riviere
Goedemoed
H E R S C H E L
Herschel
Wilgespruit
Aliwal North
Venterstad
Burgersdorp
Kraai River
Barkly East
lmietfontein
rkspruit
Telle
5000
6000

shows that there is a considerable diurnal change in temperature at all stations in the Upper Orange River area', paricularly during the coldest time of the year. This considerable diurnal change in temperature, which is consistent over the whole year, is the cause of the high value for the mean annual range in temperature, that is characteristic for the central part of South Africa. The annual average of the daily range in temperature differs from 13,5°C at P.K. le Roux Dam to 17,5°C at Griquatown and tends to be lowest at the sheltered stations.

TABLE II.4 MEAN MONTHLY TEMPERATURES IN °C

Station	Mohaleshoek		Aliwal North		Bethulie		Fauresmith		Andriesfontein	
SL	30° 09'		30° 41'		30° 30'		29° 46'		30° 57'	
EL	27° 28'		26° 43'		25° 58'		25° 19'		24° 36'	
Altitude (m)	1600		1332		1274		1382		1359	
Period (years)	20	0	16	7	20	13	20	18	18	0
At (S.A.S.T.)	0800	1400	0800	1400	0800	1400	0800	1400	0800	1400
January	19,6	-	20,0	28,2	20,9	29,7	20,6	28,7	19,6	-
February	18,6	-	18,8	27,1	19,5	28,2	19,2	27,4	18,7	-
March	16,7	-	16,0	25,1	16,8	25,6	17,0	24,9	15,9	-
April	12,9	-	11,5	21,3	12,1	22,2	12,5	21,7	11,2	-
May	8,3	-	6,5	17,8	6,9	18,8	7,4	18,0	5,9	-
June	5,2	-	1,5	15,0	2,6	15,9	3,0	15,3	1,3	-
July	5,1	-	1,3	15,9	2,4	15,9	2,6	15,4	1,0	-
August	8,6	-	5,4	17,9	6,0	18,8	6,6	18,1	4,3	-
September	12,2	-	10,7	19,9	11,1	12,6	11,8	21,4	9,3	-
October	16,0	-	13,9	24,3	15,4	24,7	15,9	24,1	14,2	-
November	17,2	-	17,4	24,9	18,0	26,7	18,1	26,0	17,3	-
December	19,0	-	19,5	27,6	20,6	28,3	20,3	28,1	19,3	-
Year	13,3	-	11,9	22,1	12,7	23,0	12,9	22,4	11,5	-

The average daily minima for the coldest month (July) are, except at Hopetown and at the sheltered stations P.K. le Roux Dam, Mohaleshoek and Hendrik Verwoerd Dam, all below freezing point. The lowest values are again found at the plateau stations Andriesfontein and Fauresmith. The absolute minimum temperatures recorded at these stations do not differ much from most of the other stations, however, with the exception of P.K. le Roux Dam. Three stations, Bethulie, Oviston and Griquatown, have only one month with a mean daily temperature below freezing point, while three, Aliwal North, Venterstad and Fauresmith, experience two months with a mean daily temperature below freezing point, and at Andriesfontein this period is three month.

The number of months with an absolute daily temperature lower than 0°C differ considerably from station to station. P.K. le Roux Dam has recorded only two, Hendrik Verwoerd Dam three, Oviston four, Venterstad and Hopetown six, Bethulie, Fauresmith and Griquatown seven, Aliwal North and Andriesfontein eight and Mohaleshoek nine. It should again be emphasized that the first three stations have only kept temperature records for five years. From six stations the period over which frost occurs and the number of days with frost have been recorded. The data are listed in table II.5.

TABLE II.5 AVERAGE DURATION OF FROST PERIOD AND NUMBER OF FROST-DAYS

Station	Mohaleshoek	Aliwal North	Fauresmith	Andriesfontein	Hopetown	Griquatown
SL	30° 09'	30° 41'	29° 46'	30° 57'	29° 37'	28° 51'
EL	27° 28'	26° 43'	25° 19'	24° 36'	24° 05'	23° 15'
Altitude (m)	1600	1332	1382	1359	1098	1311
Period (years)	28	16	20	25	11	16
Average duration of frost period (days)	138	135	132	165	102	127
Average annual number of frost-days	38,8	65,4	64,9	78,9	-	-

The occurrence of frost is also strongly related to topography. Owing to the high altitude and the sheltered position of Mohaleshoek, the average duration of the frost period is slightly higher than at Aliwal North and Fauresmith, but the actual average number of frost days is just over half of the number at these last two stations. Andriesfontein, showing the lowest absolute minimum temperature, also shows the longest average frost period and the largest number of frost days.

The average daily maxima for the warmest month (January) show a slight increase following the course of the river, with exceptions for the plateau stations Fauresmith and Andriesfontein, and with a maximum value at P.K. le Roux Dam. Although there is a temperature increase over South Africa from east to west, in considering these values of average daily maxima for the warmest month, it should be kept in mind that there is also a decrease in altitude of the stations from east to west. The absolute maxima for the eleven stations do not differ very much from one another. The highest value is again recorded at P.K. le Roux Dam.

It is interesting to note that data from the Weather Bureau (1965a) for the central regions of South Africa show that there are annually about 210 days with temperatures rising as from the previous day, and about 155 days with temperatures decreasing as from the previous day. This means that on the whole the temperature rises more often than falls. It also implies that the temperature is inclined to fall abruptly by larger amounts, and that such a fall is compensated for by small rises over more successive days. This holds throughout all seasons. It has been calculated that cold periods (periods of successive days with fall in temperature) tend to last for only two or three days, whereas warm periods (periods of successive days with increase in temperature) last most frequently three to four days.

An overall picture of the temperature pattern in southern Africa can be obtained from JACKSON (1961). On JACKSON's maps (1961) surface temperatures are adjusted to a standard level of 1 250 m, being the average height of the South African plateau. This was thought to be better than to adjust surface temperatures to sea level, for the specific situation in South Africa, where on the west coast there is a nearly isothermal atmosphere up to plateau level, whilst in the east the lapse rate is about 0,6°C per 100

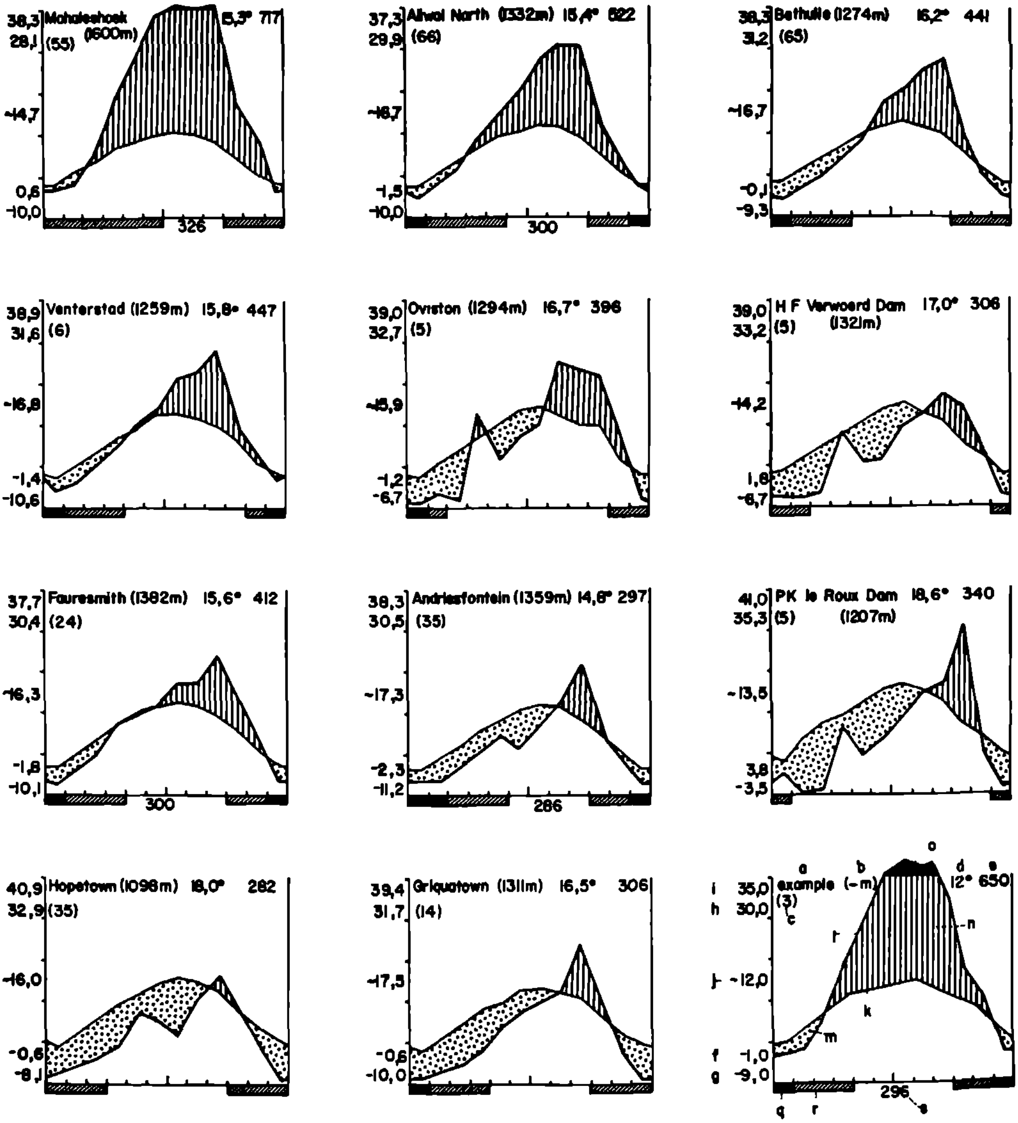


Fig. II.3 Climate diagrams of eleven stations in the Upper Orange River area. *Example*: a. name of station; b. altitude (m); c. number of years of observation; d. mean annual temperature (°C); e. mean annual precipitation (mm); f. mean daily minimum temperature of coldest month; g. absolute minimum temperature; h. mean daily maximum temperature of hottest month; i. absolute maximum temperature; j. mean range of temperature; k. curve of mean monthly temperature (1 unit = 10°C); l. curve of mean monthly precipitation (1 unit = 20 mm); m. dry season; n. wet season; o. mean monthly precipitation over 100 mm (reduced to 1/10); q. months with mean daily minimum temperature under 0°C; r. months with absolute daily minimum temperature under 0°C; s. mean duration of frost free period (days).

metres (Weather Bureau, 1965a). JACKSON (1961) used for his maps a lapse rate of 0,75°C per 100 metres for maximum temperatures and 0,5°C for mean temperatures.

II.2.4 Wind

Records on wind direction and speed have been kept by two stations along or near the Upper Orange River, Bethulie and Fauresmith, for 10 years (Weather Bureau, 1960). Table II.6 summarizes the data for these two stations.

TABLE II.6 WIND DATA

Station	Bethulie	Fauresmith
SL	30° 30'	29° 46'
EL	25° 58'	25° 19'
Altitude (m)	1274	1382
Period (years)	10	10
Frequency % of wind direction from:		
N	15,8	16,8
NE	7,5	5,7
E	7,2	6,4
SE	4,6	13,6
S	7,4	7,7
SW	7,4	5,3
W	17,0	9,2
NW	24,4	18,2
Calm	8,7	17,1
Average wind speed over whole year (km/hr)	19,8	10,1
Resultant wind speed for January (km/hr)	7,4	2,6
Resultant wind speed for July (km/hr)	7,8	2,6
Resultant wind direction for January	NW	N
Resultant wind direction for July	NW	NW
Sector of most frequent wind for:		
January	NW+NNW+N	NNW+N+NNE
with frequency	29,3	26,6
July	WNW+NW+NNW	NW+NNW+N
with frequency	38,8	26,3
Year	WNW+NW+NNW	NW+NNW+N
with frequency	32,5	26,1

These data show clearly that the prevailing wind direction for the whole year is NW at Bethulie and between NW and N at Fauresmith. The total percentage calm at Fauresmith is twice that at Bethulie and the average wind speed for the whole year at Fauresmith is only half that at Bethulie. The data for January and July show that there is no seasonal change in wind speed at both stations and only a slight change in wind direction at Bethulie. At Fauresmith winds of over 60 km/hr have never been recorded and at Bethulie only seldomly. Data from the Weather Bureau (1960) show that there is a slightly windier period during August in the central area of South Africa. Apart from the general wind from the NW, short but strong winds occur from the southwesterly sector during summer. They are almost always associated with thunderstorms. During hot summer days whirlwinds or dust-devils occur over the entire Upper Orange River area. They are caused by strong convection. Duststorms, associated with thunder conditions, also occur infrequently over the area. They are favoured by the small amount of plant cover in the area.

In winter the diurnal variation in windspeed shows a maximum at noon or in the early afternoon, but in summer there is no regular pattern. Usually the wind reaches a maximum speed during the afternoon or early evening. During winter there is no perceptible diurnal change in wind direction, but in summer there is usually an anti-clockwise change during the day from N to W (Weather Bureau, 1960).

II.2.5 Relative humidity and saturation deficit

Relative humidity of the air is the degree of saturation as a percentage (100 times vapour-pressure, divided by the saturation vapour-pressure). It is the direct measure of the degree of moistness of the atmosphere irrespective of its temperature. Records on mean, maximum and minimum relative humidity have been kept by four stations along or near the Upper Orange River and are summarized in table II.7 (Weather Bureau, 1954, 1965a). As pointed out by the Weather Bureau (1965a) it is more fruitful to compare the data at 1400 hrs S.A.S.T. than at 0800 hrs S.A.S.T., because in the afternoon the relative humidity at all stations is at a steady minimum for at least two hours, and the surface air is not stratified anylonger but thoroughly mixed through turbulence. In the morning this is not so, and at that time of the day the relative humidity changes rapidly, so that differences in geographical position (local time) strongly effect the records from the various stations. From the 1400 hrs S.A.S.T. figures in table II.7 it can be concluded that the average annual relative humidity at 1400 hrs S.A.S.T. tends to decrease slightly in a westward direction. Around March the mean relative humidity is highest (Aliwal North shows highest figures for February, May and June, but has records for 7 years only).This is the same period at which the precepitation is maximal (see Chapter II.2.7). The lowest average relative humidity at 1400 hrs S.A.S.T. is usually reached during early summer (December) in the Upper Orange River area. December is also the month with the absolute minimum relative humidity, although that value can be reached during other months as well. The relative humidity is not inversely correlated with temperature in the Upper Orange River area, because the influx of moist air in the warm season is sufficientto counteract the effect of rising temperature (Weather Bureau, 1965a). In the Upper Orange River area the periodicity of the variation in relative humidity falls midway between temperature and rainfall periodicity.

The diurnal variation in relative humidity at each station is large. It is more or less inversely correlated with the diurnal variation in temperature. In winter the diurnal variation of relative humidity and of temperature is largest.

The saturation deficit can be expressed in terms of saturation vapour-pressure (E),actual vapour-pressure (e) and relative humidity (r). The saturation deficit (E-e) then equals the product of saturation vapour-pressure and unity minus one hundredth of relative humidity. Saturation deficit is not directly proportional to evaporation, since the latter is also dependent on other factors such as wind velocity.

TABLE II.7 RELATIVE HUMIDITY OF THE AIR IN PERCENTAGES

Station	Mohaleshoek				Aliwal North				Bethulie				Fauresmith			
SL	30° 09'				30° 41'				30° 30'				29° 46'			
EL	27° 28'				26° 43'				25° 58'				25° 19'			
Altitude (m)	1600				1332				1274				1382			
Period (years)	20		-		16		7		20		13		20		18	
At (S.A.S.T.)	0800		1400		0800		1400		0800		1400		0800		1400	
relative humidity	mean	max.	mean	min.	mean	max.	mean	min.	mean	max.	mean	min.	mean	max.	mean	min.
January	61	78	-	-	64	75	35	26	59	73	28	19	57	76	28	18
February	65	79	-	-	70	79	42	29	67	77	37	22	64	74	32	16
March	70	83	-	-	79	90	39	33	74	85	41	20	71	87	37	18
April	71	88	-	-	77	88	40	26	73	82	41	28	72	86	36	20
May	74	86	-	-	82	93	42	31	78	89	38	17	75	88	36	25
June	69	80	-	-	79	88	42	37	77	84	40	37	76	85	36	30
July	67	82	-	-	78	89	37	31	74	89	35	29	73	82	32	25
August	59	81	-	-	67	79	36	24	63	76	32	17	62	78	31	20
September	56	83	-	-	62	75	32	25	58	77	36	21	51	68	27	18
October	57	83	-	-	61	74	33	27	57	79	33	21	52	65	27	14
November	59	89	-	-	63	80	34	17	57	69	30	21	55	80	30	18
December	60	84	-	-	61	71	31	14	55	70	28	17	53	68	27	14
Year	64	-	--		72	-	37	-	66	-	35	-	63	-	32	-

Maps from the Weather Bureau (1965a) show that the entire Upper Orange River area in January falls in the zone where the mean saturation deficit at 1400 hrs S.A.S.T. is between 25 mb in the east and 40 mb in the west. In April these values are between 15 mb in the east and 20 mb in the west; in July between 12 mb in the east and 15 mb in the west; in October between 20 mb in the east and 30 mb in the west. Taken over the whole year, the area falls in the zone between 15 mb in the east and 25 mb in the west. Thus, the mean saturation deficit at 1400 hrs S.A.S.T. in the Upper Orange River area shows a gradient that increases westward and correlateswith the temperature gradient and with the inverse of relative humidity. The mean saturation deficit at 1400 hrs S.A.S.T. in the Orange River area is lowest during winter and highest during summer. The gradient from east to west is steepest in summer.

The diurnal change in saturation deficit in the Upper Orange River area is large and according to a tentative map of the Weather Bureau (1965a) larger in summer (between 20 and 25 mb) than in winter (between 12 and 15 mb).

II.2.6 Evaporation

Only two stations, Aliwal North and Fauresmith, that keep records on evaporation, are located close enough to the Upper Orange River to be discussed here. At Aliwal North evaporation is measured by means of both a class "A" (American) evaporation pan and a Symons pan, and at Fauresmith only by means of a class "A" pan. The records at both stations have been kept over a period of four years and summarized in table II.8. A class "A" pan is circular, with a diameter of 1,22 m (4 feet), a depth of 25,4 cm (10 inches), and is exposed completely above the ground on a wooden frame-work, that permits ventilation underneath the pan. A Symons pan is square, with sides of 1,83 m (6 feet), a depth of 61 cm (2 feet), and is sunk into the ground to a depth of 53 cm (21 inches) (Weather Bureau, 1965a).

TABLE II.8 MONTHLY, SEASONAL AND ANNUAL EVAPORATION IN mm

Station	Aliwal North		Fauresmith
SL	30° 41'		29° 46'
EL	26° 43'		25° 19'
Altitude (m)	1332		1382
Period (years)	4		4
Type pan	Symons	Class "A"	Class "A"
January	218	284	348
February	191	249	295
March	147	193	251
April	99	132	168
May	58	84	107
June	43	64	81
July	53	81	104
August	86	130	147
September	127	178	239
October	175	236	295
November	216	264	333
December	218	284	366
Year	1633	2179	2733
Summer (in %)	38	38	37
Autumn (in %)	19	18	19
Winter (in %)	11	13	12
Spring (in %)	32	31	32

These figures indicate that evaporation also shows an increase in the downstream direction of the Orange River, just as the saturation deficit and the temperature do. The annual range in evaporation also tends to increase in this direction. The evaporation is highest during early summer (December, January) and lowest during early winter (June). As will be seen in Chapter II.2.7, the time of minimal evaporation coincides with the time of lowest precipitation.

Although the total values for Aliwal North are consistently lower than those for Fauresmith, the percentual figures for each season are the same at both stations.

II.2.7 Precipitation

Rainfall statistics are available from 49 stations in or near the Orange River valley (Weather Bureau, 1965b, 1967a, b, 1968, 1970, 1971). Data are given in table II.9. The column "position" refers to the position of the rainfall station in relation to the Orange River valley. If a station is situated in the Orange River valley, this is indicated by "v". The stations Bleskop and Bakovenspan are also included in this category, because they lie on an extensive plain at only slightly higher altitude than the levees of the Orange River. If a station is located in a side valley that is directly open towards the Orange River, it is indicated by "so"; if the side valley is not completely open towards the Orange River, in such a way that there is a considerable elevation in the landscape on a straight line between the station and the Orange River valley, this is indicated by "sc". If a station is located on a plateau, high above the bed of the Orange River, and it is open toward the Orange River valley, it is indicated by "po"; if there is a considerable elevation on the plateau on a straight line between the station and the Orange River valley, this is indicated by "pc". The raingauges are placed at a level of 1,20 m above the ground.

It can be seen from table II.9 that the precipitation decreases along the river course from a mean annual amount of over 600 mm to less than 300 mm. The maximum amount of rain generally falls during March, although a few local deviations may occur. In case of such an exception, March is usually the month with the second highest precipitation, with figures close in value to the highest amount. In a number of cases exceptions will be due to the short period of recording, like the October values for Oviston. The driest month is usually June, although frequently July also shows the lowest rainfall figures. This suggests that for the entire Upper Orange River the driest time of the year is during the second half of June and the first half of July. Thus, the asymmetrical distribution of the precipitation over the year is clearly shown in table II.9. After the maximum in March, the minimum is reached very soon, from which there is again a gradual increase over the year towards the maximum. The rainfall map of MACKENZIE (1945) agrees well with the figures in table II.9. The 25 inch (635 mm) isohyet forms a large eastward pocket between Herschel and Zastron, and reflects some correlation with the topography of the area. Just downstream of Aliwal North the 20 inch (508 mm) isohyet crosses the Orange River. The 15 inch (381 mm) isohyet forms an eastward pocket between Venterstad and Bethulie and runs from there more or less parallel and to the right hand side of the Orange River valley until the vicinity of Petrusville, where it turns northward. On its parallel tract this isohyet just crosses the valley north of Colesberg. The rainfall figures for Rietbult confirm this. In the same way the low rainfall figures for Bakovenspan reflect the eastward pocket of the 10 inch (254 mm) isohyet between Hopetown and De Aar.

An insight into the rainfall pattern of the area in relation to the whole of southern Africa can be acquired from JACKSON (1961). These maps show mean monthly rainfall and monthly percentage of mean annual rainfall. According to data from the Weather Bureau (1965a, b) there is a slight diurnal variation of precipitation in the Upper Orange River area. The maximum seems to fall in the afternoon and early evening, the minimum in the late morning. In the Upper Orange River area the rain falls usually in thunder-

TABLE II.9 RAINFALL DATA OF THE UPPER ORANGE RIVER VALLEY

Station	Position	SL	EL	Alt. (m)	Distance from Riverbed (km)	Period (years)	Jan.
Palmietfontein	v	30° 25'	27° 32'	1326	1,5	10	122,
Kornetspruit	sc	30° 16'	27° 21'	1486	5,0	35	82,
Halma	po	30° 23'	27° 23'	1478	1,0	29	79,
Sterkspruit	pc	30° 31'	27° 22'	1454	7,0	60	93,
Quaggafontein	so	30° 28'	27° 14'	1372	2,5	32	71,
Herschel	po	30° 37'	27° 10'	1554	8,0	66	97,
Broederstroom	po	30° 32'	27° 01'	1341	1,5	20	78,
Morgenson	pc	30° 38'	27° 02'	1417	3,5	26	84,
Klipdam	sc	30° 35'	26° 55'	1370	3,5	6	79,
Lusthof	so	30° 38'	26° 48'	1370	2,0	7	72,
Aliwal N. - prison	v	30° 41'	26° 43'	1356	0,0	71	75,
Aliwal N.-municipality	v	30° 42'	26° 42'	1356	0,0	60	89,
Sanddrift	v	30° 37'	26° 30'	1295	0,0	18	57,
Erfeniskraal	pc	30° 33'	26° 26'	1372	2,0	24	45,
Goedemoed police	v	30° 33'	26° 26'	1311	0,0	42	63,
Oudefontein	v	30° 35'	26° 21'	1326	1,0	5	53,
Wintershoek	v	30° 29'	26° 12'	1372	1,5	28	47,
Eerstestap (x)	v	30° 32'	26° 02'	1311	0,0	30	50,
Bethulie	v	30° 30'	25° 58'	1274	4,0	67	61,
Luckno (x)	v	30° 32'	25° 55'	1265	0,0	29	46,
De Rust (x)	v	30° 40'	25° 50'	1356	3,0	18	51,
Oviston	v	30° 42'	25° 46'	1294	0,0	5	39,
Klipfontein (x)	v	30° 40'	25° 45'	1250	0,0	22	53,
Hendrik Verwoerd Dam	v	30° 37'	25° 30'	1321	0,0	5	38,
Norvalspont	v	30° 38'	25° 28'	1219	1,0	35	41,
Tweefontein	v	30° 34'	25° 25'	1250	2,5	37	39,
Rietbult	v	30° 30'	25° 13'	1204	1,0	25	60,
Olivewood	sc	30° 24'	25° 00'	1173	4,5	41	33,
Kareepoort	po	30° 16'	25° 06'	1341	7,0	45	42,
Nooitgedacht	pc	30° 11'	24° 55'	1227	5,5	28	38,
Kalkfontein	pc	30° 03'	24° 56'	1234	10,0	7	22,
Blouboshoek	pc	30° 01'	24° 56'	1270	11,0	10	48,
Boshoffsdam	pc	29° 57'	24° 52'	1250	9,0	15	37,
Tevredenheid	pc	29° 57'	24° 49'	1227	6,0	51	38,
Boschrand	pc	29° 55'	24° 49'	1219	8,0	17	37,
Petrusville	pc	30° 05'	24° 40'	1212	11,0	61	44,
P.K. le Roux Dam	v	30° 00'	24° 44'	1207	0,0	5	37,
Vissersdrift	v	29° 57'	24° 41'	1158	4,0	35	33,
Bleskop	v	29° 50'	24° 36'	1109	5,0	30	35,
Bakovenspan	v	29° 48'	24° 19'	1097	9,0	24	17,
Zoutpansdrift	v	29° 43'	24° 22'	1112	0,0	22	26,
Thorndale	v	29° 42'	24° 21'	1090	1,0	14	35,
Oranjerivier - station	v	29° 38'	24° 13'	1073	2,5	73	34,
Hopetown - prison	v	29° 37'	24° 05'	1098	2,0	81	40,
Hopetown - old bridge	v	29° 34'	24° 05'	1067	0,0	7	42,
Eskdale	po	29° 27'	24° 00'	1097	2,0	14	55,
Torquay	v	29° 16'	23° 50'	1067	0,5	5	33,
Douglas - prison	sc	29° 03'	23° 46'	1030	10,0	70	46,
Bucklands	so	29° 04'	23° 40'	1006	2,0	22	42,

Stations marked with (x) are presently drowned by the water of the Hendr

Average Rainfall (mm)

eb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Year
00,3	94,2	64,0	34,0	20,3	11,9	13,5	40,9	56,1	62,0	97,3	717,2
83,9	95,9	52,4	28,3	10,7	15,2	16,2	27,5	58,8	71,6	95,4	638,2
85,3	86,8	56,0	35,7	9,6	14,0	14,2	24,9	50,2	70,4	93,3	619,7
97,1	98,5	52,1	32,0	12,2	12,8	13,2	31,1	50,6	68,1	90,8	651,9
72,2	94,8	49,0	29,2	7,5	12,4	12,5	25,5	44,0	56,6	73,3	548,4
95,3	103,1	57,2	35,4	16,0	13,4	20,5	29,9	51,9	66,6	82,3	669,2
76,1	80,2	55,0	30,6	8,4	10,4	17,9	22,1	53,1	53,5	59,5	545,5
75,5	87,0	48,5	37,4	7,0	12,6	15,1	20,4	48,4	66,5	57,8	560,2
84,4	92,9	47,0	36,6	3,9	4,1	11,5	18,2	50,7	86,8	49,1	564,2
77,6	80,3	36,8	32,3	6,7	12,7	9,7	25,8	36,4	59,1	63,3	512,8
80,9	81,4	44,5	28,1	13,2	10,2	15,7	23,3	39,0	53,9	62,1	527,5
95,0	94,2	46,2	27,7	16,0	13,0	17,5	24,1	39,1	58,9	70,6	592,0
69,2	70,6	60,0	37,3	5,6	8,5	13,0	11,0	31,5	48,0	48,4	460,4
57,7	72,9	20,0	16,5	8,6	7,6	11,9	29,1	28,7	41,4	42,4	382,4
61,0	79,2	42,2	26,2	7,4	10,5	14,1	19,4	33,8	58,6	57,6	473,3
90,9	70,1	43,4	34,0	10,4	6,1	8,1	12,2	20,8	30,2	83,1	462,9
53,5	76,1	41,5	22,7	4,1	9,2	9,8	16,8	28,1	37,8	49,5	396,9
53,6	66,8	33,3	16,5	5,1	5,3	12,7	17,3	25,7	42,2	40,6	369,9
71,3	74,8	41,2	21,1	9,7	8,9	11,7	19,4	30,1	37,9	53,9	441,1
55,8	62,1	44,6	28,2	5,1	9,3	10,4	17,1	26,5	37,7	43,3	386,2
44,7	50,0	36,1	18,8	6,6	8,6	14,5	24,9	28,2	41,9	35,6	361,2
69,7	68,1	64,3	30,1	4,4	2,0	6,7	3,8	44,0	22,9	35,7	396,1
56,9	72,9	36,1	23,6	6,9	6,4	12,7	21,1	29,0	52,1	44,5	415,8
45,3	54,7	47,5	28,6	5,6	5,1	4,5	6,7	35,8	22,2	23,3	306,5
55,8	62,9	34,9	28,3	5,4	8,5	10,2	17,6	25,9	37,2	42,4	370,2
59,0	67,4	38,4	25,9	6,3	7,4	11,4	13,6	25,8	40,4	41,4	376,6
62,2	66,0	33,8	23,9	14,5	7,4	9,4	13,7	22,8	29,8	38,9	382,3
55,9	65,3	37,2	24,7	5,8	7,5	11,5	13,9	23,3	31,5	33,5	343,4
56,8	74,0	35,0	26,4	6,8	15,6	12,3	16,8	23,7	38,8	39,4	386,4
46,3	58,4	36,0	25,1	3,1	7,4	11,2	15,7	24,9	35,7	35,9	338,2
77,0	70,9	25,4	14,2	3,8	3,8	5,3	14,2	27,7	34,0	22,4	320,9
42,2	60,5	20,8	19,6	6,9	5,6	9,4	15,8	33,0	41,4	42,9	346,1
52,0	79,9	52,4	26,0	7,0	9,9	13,8	14,4	28,2	35,2	41,4	397,5
53,0	70,9	37,2	22,8	7,2	7,9	11,7	13,2	26,1	37,4	36,1	362,4
39,4	79,0	32,8	21,1	5,6	6,1	10,7	15,2	24,1	45,0	40,1	356,7
50,6	65,8	36,3	23,9	7,0	7,6	10,1	17,9	25,9	32,5	36,2	358,6
48,5	55,3	82,3	21,1	2,6	10,0	1,0	2,5	32,4	19,3	27,4	339,9
50,3	69,9	32,0	20,6	3,8	5,6	9,9	16,5	22,9	32,0	34,5	331,0
54,1	54,5	38,1	20,4	4,9	6,8	10,5	11,3	27,8	33,0	35,6	332,9
40,9	44,4	28,9	13,8	1,7	5,0	6,8	10,3	20,5	33,6	23,6	246,8
49,3	46,7	36,8	19,8	2,8	6,4	9,4	13,2	26,2	40,1	31,2	308,3
49,0	77,5	21,3	14,5	2,0	4,8	11,2	12,5	11,9	23,1	29,7	293,3
41,5	55,0	25,0	16,2	6,2	4,5	6,6	10,8	16,4	27,2	27,0	270,7
46,1	62,0	31,9	20,3	6,8	5,9	7,5	11,6	19,4	31,2	29,6	313,0
42,2	57,7	27,2	22,6	7,1	4,6	10,9	10,7	23,6	29,2	14,2	292,4
42,4	66,3	37,6	17,0	13,7	4,6	3,8	9,7	18,0	26,7	38,4	333,8
49,2	48,1	16,6	30,3	9,5	2,8	9,1	7,0	13,5	37,5	38,0	294,7
60,0	69,3	29,1	16,7	4,3	3,7	6,8	10,4	18,5	26,9	33,7	325,7
48,8	69,1	18,8	12,2	2,0	2,5	7,1	11,2	15,5	30,5	32,0	292,4

erwoerd Dam.

storms, which means that it is of great intensity but lasts for short periods of time only. This is also indicated by the frequency of days with thunder in the area. In the east near Sterkspruit an average annual number of 70 days with thunder occur and in the west near Griquatown this figure is 40 (Weather Bureau, 1965a). For some stations the frequency of the number of days with thunder is even higher than the number of days with rain. The reasons for this are twofold. Firstly, rainfall is recorded at a certain point, whereas thunder is heard from some distance from that point, and rain may have occurred in the vicinity of the rainfall station but not at the station itself. Secondly, it frequently occurs in the Upper Orange River area, and actually over the largest part of South Africa, that the rain can be seen falling in streaks (virga), but it evaporates, due to the hot dry surface air, before it ever reaches the ground.

Associated with thunderstorms, precipitation in the form of hail is not rare in the Upper Orange River area. A generalized map of the Weather Bureau (1965a) shows that the figure for the average number of days per annum with hail decreases from 5 in the Sterkspruit area to 1 in the Griquatown area. Hail occurs most frequently in November, in the late spring.

Few reliable data are available on the frequency and intensity of snow fall. Although it can occur rarely over the entire Upper Orange River area, it i most frequent in the higher parts, particularly in the area around Sterkspruit during the end of June. On the mountains of the southeastern escarpment (Drakensberg) snow falls on an average eight times per year (Weather Bureau, 1965a).

II.2.8 Climatological classifications

Based on meteorological statistics from many observation points several climatological maps of southern Africa have been produced according to different criteria for classification.

KÖPPEN & GEIGER (1936) used precipitation and temperature characteristics for a classification system of the climates of the world in such a way, that the limits and boundaries fitted into known vegetation distribution patterns (STRAHLER, 1960). In 1928 KÖPPEN & GEIGER produced a "Klimakarte der Erde", which shows only 8 climate types in southern Africa. This section of the map was based on records from only 65 stations and therefore was rather imprecise. The classification of the climates of South Africa according to the KÖPPEN & GEIGER system was greatly improved by SCHULZE (1947), who used data from 504 stations. On SCHULZE's map the Upper Orange River area falls mainly in the category BSkw' (steppe climate, cold and dry, with a mean annual temperature below 18°C, but the mean temperature of the warmest month exceeding 18°C, dry in winter, rainy season in March and April). Upstream of Sterkspruit the climate is of the class Cwb (warm temperate, rainy climate, with dry winters, mean temperature of the warmest month over 22°C, of the coldest month below -3°C, and with at least one month with a mean temperature below 18°C and eight months with a mean temperature exceeding 1°C). Between Hopetown and Douglas there is a narrow zone just falling in BWkw' (desert climate, cold and dry, with a mean annual temperature below 18°C, but the mean temperature of the warmest month exceeding 18°C, a dry winter and the rainy season during March and April). The lowest part of the

Orange River valley falls in the class BShw' (steppe climate, dry and hot with a mean annual temperature over 18°C, a dry winter with the rainy season during March and April). In the part downstream of Hopetown the boundary between the classes BWkw' and BShw' runs very close and nearly parallel to the river. The distribution of these four climatic types over the Orange River valley is shown diagrammatically in fig. II.9.

SCHULZE (1947) also classified the climates of South Africa according to the THORNTHWAITE system (1931). THORNTHWAITE's system is based on the relationship between precipitation, evaporation and temperature. SCHULZE (1947) considers THORNTHWAITE's system to give a good picture of the effectiveness of precipitation when used in a detailed survey of a small area, but as a truly climatic classification system it is inferior to KÖPPEN & GEIGER's system. Another major objection against THORNTHWAITE's system is that it fails to give an adequate picture of seasonal variation (SCHULZE, 1947). POYNTON (1971), in preparing a silvicultural map of southern Africa, found the thermal regions as proposed by the THORNTHWAITE system not entirely satisfactory. POYNTON considered it necessary to subdivide the mesothermal zone, which includes nearly all of southern Africa, on the basis of mean monthly minimum temperature for July rather then on the basis of potential evapotranspiration. The Upper Orange area falls into three different classes of the THORNTHWAITE system: East of Aliwal North CB'd (sub-humid warm climate with deficient moisture in all seasons); between Aliwal North and Hopetown DB'd (semi-arid warm steppe climate) and west of Hopetown EB'd (arid warm desert climate) (SCHULZE, 1947). Thus the KÖPPEN & GEIGER and the THORNTHWAITE systems agree that the border between steppe and desert climates lies near Hopetown, and another major climatic boundary runs not far east of Aliwal North.

JACKSON (1951) rejects the value of climatic classification systems like the ones of KÖPPEN & GEIGER and THORNTHWAITE, pointing out that British climatologists are suspicious of these pseudomathematical works and that climates are too complex to be defined that way. He emphasizes that one should keep in mind the purpose the climatic characterization is intended to serve. He divides southern Africa into eight climatic regions, of which the boundaries are not defined by any fixed criterion, although they are often isohyets. These boundaries should be regarded as zones of transition in which the climates change from the types on the one side to those on the other, slowly or rapidly. Short climatological descriptions in general terms of the eight climatic regions are then given. The Upper Orange River area is covered by two regions: The eastern plateau of South Africa, and the semi-arid plateau interior. The boundary between these two regions runs between Aliwal North and Bethulie, and is formed by the 20 inch (50,8 cm) isohyet (JACKSON, 1951).

Of interest for this survey are three climatic classification systems that are especially developed in regard to vegetation or biocoenoses (WALTER & LIETH, 1960; UNESCO-FAO, 1963; TROLL & PAFFEN, 1964) and are discussed below.

In order to be able to compare details in the climates of geographically widely separated localities WALTER & LIETH (1960) developed a technique for the construction of climatic diagrams for every station on the globe that keeps meteorological records of at least precipitation and temperature. They used temperature data, because evaporation data are available from only a limited number of stations. Precipitation and temperature are two factors that play an important role in the water balance of the plant body. Some extreme values, such as absolute minimum and maximum temperatures, number of days with frost per year and the average daily range in temperature are also of considerable importance in the physiology of the plant, and are therefore also included in the climatic diagram of each locality. By means of hatching the humid and dry period of the year is indicated in the diagram. WALTER & LIETH (1960) emphasize that although the climatic diagrams usually give a good picture of the local climatic situation they are of restricted value in ecological and applied biological studies for the following reasons (compare also GEIGER, 1965): Firstly, all recordings are taken under protection from radiation, whereas the plants receive unlimited solar radiation. This influences their water balance, temperature and photosynthesis rate. Secondly, all data are recorded at a level of 1,20 m above the ground, in order to avoid disturbances caused by the lowest atmospheric layers. These layers are, however, of overriding importance for most plants. Thirdly, climatic diagrams give the means of a longer period. Plants are exposed to irregular deviations of the normal pattern, and extremities are usually of major importance.

Climate diagrams for eleven stations in the Upper Orange River area given in fig. II.3. Some stations have kept records for a short period only, and cannot be regarded as giving a reliable picture of the local climate, especially in regard to extremities in precipitation. The Upper Orange River area is crossed by two type boundaries (WALTER & LIETH, 1960). Between Aliwal North and Goedemoed runs a boundary, upstream of which the area falls into the regime of type II3a. West of this boundary until the neighbourhood of P.K. le Roux Dam the area falls into type II4a (type II is a tropical or subtropical summer rainfall area; subdivision has not yet been characterized). Downstream of P.K. le Roux Dam the river enters type II(III)a (arid tropical or subtropical summer rainfall area; subdivision not yet characterized), which extends to Brakrivier near Prieska.

In an attempt to exhibit the ecological conditions of mediterranean areas as fully as possible in a bioclimatic and a vegetation map, UNESCO-FAO (1963) point out that it is important to use only meteorological data for the bioclimatic map. But these meteorological data must be those that have a definite action on plants, "for all living entities, plants are the only ones wholly of the climate of their habitat". Ombrothermic diagrams and xerothermic indices are then chosen as criteria in defining the bioclimatic zones. In an ombrothermic diagram, just as in WALTER & LIETH's climate diagrams, temperature and precipitation are plotted against each month. The xerothermic index, or index of hot weather drought, is the sum of the monthly indices for the dry months, where a dry month is defined as a month in which the total precipitation (in mm) is equal to or less than twice the mean temperature of the month (in ^{o}C). The monthly index denotes the degree of drought of a given dry month and is defined as the number of days in the month which can be deemed dry from the biological point of view. In calculating the monthly index the number of days without rain are used, to allow for the character of showers; days with mist and dew are reckoned as half a dry day, and days without precipitation and an atmospheric humidity of 40% or lower are reckoned as a dry day, whereas they count for half a dry day when the humidity equals 100%. A sliding scale provides for estimation of dry day amounts on days with a humidity between 40% and 100%. Thus the

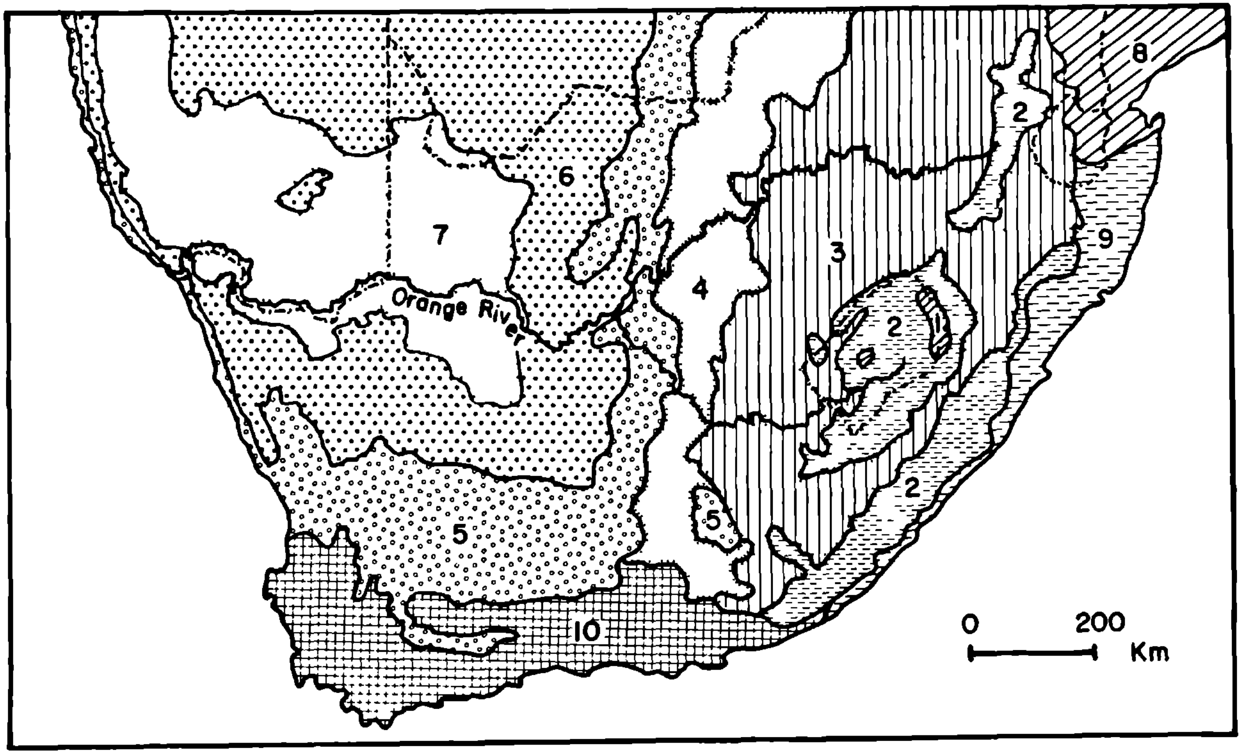


Fig. II.4 Climate map of southern Africa showing the gradient from temperate tropical climate to sub-desert climate in the Upper Orange River area. 1. cold temperate axeric climate; 2. sub-axeric and attenuated temperate tropical climates; 3. intermediate temperate tropical climate; 4. accentuated temperate tropical climate; 5. attenuated sub-desert climate; 6. accentuated sub-desert climate; 7. desert climate; 8. warm tropical climates; 9. warm axeric (sub-equatorial) climates; 10. Mediterranean climates (adapted from UNESCO-FAO, 1963).

xerothermic index gives the number of"biologically" dry days during the dry season.

According to this classification system, the Upper Orange River area is covered by three bioclimatic zones (UNESCO-FAO, 1963): From within Lesotho to Norvalspont the river flows through the intermediate temperate tropical zone; from Norvalspont to near P.K. le Roux Dam its flows through the accentuated temperate tropical zone, and from P.K. le Roux Dam to Douglas through the attenuated sub-desert zone (fig. II.4).

An intermediate temperate tropical climate is a climate with a dry period between one and eight months coinciding with the period of shortest daylight, a mean temperature of the coldest month between 0^{o} and 10^{o}C, and a xerothermic index between 100 and 150. The accentuated temperate tropical climate differs from the intermediate one in that it has a xerothermic index between 150 and 200 (long dry season). An attenuated sub-desert climate means a climate with a dry period lasting between nine and eleven months and a xerothermic index between 200 and 250.

Based on the premise that most aspects of life show a seasonal rhythm, TROLL & PAFFEN (1964) compiled a seasonal climatic map of the world based on light, radiation, temperature and precipitation. The entire Upper Orange River area falls into zone IV (warm-temperate subtropical zone with mild winters in which the temperature of the coldest month is between 6^{o} and 13^{o}C). Near Bethulie runs a subdividing boundary, east of which the area falls in type IV 4 (dry winter climate with long summer humidity, generally six to nine humid months). West of this boundary until the neighbourhood of Griquatown the area falls into type IV 3 (steppe climate with short summer humidity and dry winters; less than five humid months).

Thus, it will be noticed that whereas WALTER & LIETH (1960) and UNESCO-FAO (1963) draw the boundary between steppe or sub-desert climate and subtropical or temperate tropical climate near P.K. le Roux Dam, TROLL & PAFFEN (1964) draw it as far east as Bethulie. WALTER & LIETH (1960) and UNESCO-FAO (1963) subdivide the subtropical zone into a more arid and a less arid part with a range in boundary between Norvalspont and Aliwal North.

II.2.9 Mesoclimate and microclimate

In the previous section attention was paid to WALTER & LIETH's (1960) remarks on the differences in macroclimate and the climate near the ground. Meso- and particularly microclimatological topics are discussed in detail by GEIGER (1965). Meso- and microclimate are of primary importance in the ecology of each individual site, and since there exist only few specific South African data and findings of this nature, some facts mentioned by GEIGER will be discussed here in brief. (In South Africa AITKEN (1922) did some observations upon the effect of slope exposure near Pietermaritzburg. MüLLER (1970) carried out measurements on temperature, humidity and evaporation in a hilly area near Bloemfontein, covered with grass, bush and karroid communities, whereas temperature, humidity, evaporation and light penetration measurements were taken by VAN ZINDEREN BAKKER (1971) in and outside a ravine forest in the northeastern Orange Free State).

The three factors that have an important impact on the climate of a specific site are topography, vegetation and soil, of which particularly the first one influences the mesoclimate. Soil thickness, colour, texture, water content, drainage capacity, surface roughness, conductivity, etc. influence the radiation balance on a specific site and thus the microclimate.

Within a vegetation cover there exist substantial differences in temperature of various parts of a plant, because the different parts of the plant receive different amounts of solar radiation and lose different amounts of heat by radiation, all depending on the form of the plant and the density of the vegetation. This has its influence on the temperature in a vegetation cover at various heights. Wind speed and wind strength are also reduced by different amounts, depending on structure and density of the vegetation. This again has its effect on the relative humidity in the air layer near the ground. Because of a plant cover, the climate near the ground is milder: temperatures are lower by day and higher by night than on bare ground. Hence, although a plant covered surface evaporates more than bare ground, owing to living processes and increase of evaporative surface, a plant covered soil will not dry out as soon as bare ground, because vegetation tempers temperature extremes and reduces wind, thus favouring the moisture balance of the lowest air layers. This influences the temperature and moisture distribution within the soil.

An interesting fact about the influence of Australian open semi-desert scrub upon moisture distribution in the soil after a shower, was published by SPECHT (1958). He found that plants direct the water of the rain drops along their surfaces or deposit it in drops in the vicinity of their main root system, so that the day after the rain the highest moisture content is found in the root zone of the plants and not under the bare surface spots, where the rain could fall unhindered. The plants with the largest aerial cover had intercepted the largest quantities of rain water and deposited it in their root zone, thus favouring themselves and smaller plants in their shadow, and making the establishment of plants on bare spots more difficult.

Similar results were obtained in Kenya by GLOVER et al. (1962) in a number of open grassland communities, some of them with scattered trees and thicket clumps. They ascertained a direct relationship between the depth of rain-water penetration into the soil and the height of the plant at each spot, and between the sectional area of the wet soil mass beneath each vegetation clump and the sectional area of the clump above ground. This may partly explain the fact observed by CANNON (1924), that in the arid parts of southern Africa, succulents often grow under larger non-succulents.

Depending on geographic latitude, period of the year, time of the day, slope angle and slope direction, slopes receive different amounts of radiation. Differences in slope angle and direction cause differences in temperature during the daytime, resulting in air currents that run up-slope. At night slope direction is of no importance. The temperature distribution is regulated then by a downward flow of cold air, that has been cooled in contact with the ground and has a higher density. The result of this is a diurnal variation in slope winds. Valley winds also occur in an open valley, blowing up-valley during the daytime and down-valley at night. Because cold air does not have a high fluidity, cold air of the down-valley wind at night is dammed up, where the valley narrows. Because of the up-slope wind during the daytime, the highest temperatures near the ground occur at the bottom of a valley and at the flat mountain plateau. Apart from radiation reflection by the valley sides, temperature increases in the daytime also with decreasing altitude, making the valley a relatively hot place. At night the temperature increases with height everywhere, because of the negative radiation balance. Because of the circulation between air that is cooling on the slope and the reservoir of warmer air above the valley floor, a lake of cold air develops at the bottom of the valley. On the plateau a layer of cold air remains near the ground. Thus at night there develops an intermediate zone on the slope of the valley, the thermal belt, where temperatures are higher. The position of the thermal belt on a slope is remarkably constant, depending, however, upon many local factors at any one slope. All this results in a diurnal variation of temperature and relative humidity, that is largest at the valley bottom and smallest at the mountain top plateau. In the valley bottom frosts occur more frequently, therefore, than on the valley sides.

Between level country and neighbouring extensive mountain areas compensating winds are brought into existence, through heating differences. During the daytime the air pressure over the plain becomes higher relative to that over the mountain area, thus creating a horizontal pressure gradient, which produces a movement of air towards the mountains. At night a return flow occurs with reversal of the temperature difference.

Where the altitudinal range is not too large, the distribution of precipitation on a mountain depends largely on the wind field: rain and snow fall are higher in wind shadows than on the windward side. Virtually nothing is known with certainty about the deposition of dew on different slopes, but steepness of slope seems to have an impact on the amount of mist precipitation intercepted by plants (cf. KERFOOT, 1968). Because topography influences temperature and wind direction and strength, it influences also the relative humidity of the air layer near the ground. In the same way soil temperature and soil humidity is influenced (GEIGER, 1965).

The considerable topographical differences existing in the Upper Orange River area will thus be of relatively great importance on the meso- and microclimate and ecology of individual sites. This will have its reflection in the composition and distribution of the plant communities of the area. That these topographical differences have their impact on the mesoclimate of the various localities is shown by the deviating climatological records of stations like Mohaleshoek and P.K. le Roux Dam. In previous sections occasional reference has been made to it.

II.3 GEOLOGY

The geological conformation of Africa south of the Zambezi is, in general, relatively regular and symmetrical and particularly in the central parts of South Africa this symmetry of geological strata in all directions from the highest points of the escarpment is striking.

The geological history of southern Africa has been divided into some fifteen systems, each of them consisting of all the strata laid down within the period of an entire geological revolution. These strata have been formed under comparatively steady or progressively altering geological conditions, frequently modified by disturbances due to oscillations of the land relative to the sea, or arising out of climatic variations (DU TOIT, 1954). Systems are subdivided in series, series in stages, and stages consist of zones or horizons.

The whole of the Upper Orange River flows virtually over strata of just one system, the Karoo System, which is correlated with the period from Upper Carboniferous to Jurassic in the European stratigraphy. Only in the lowest part of the Upper Orange River area outcrops of lavas of the Ventersdorp System, that is of Precambrian age, occur (fig. II.5) (TRUTER & ROSSOUW, 1955; COERTZE & SCHIFANO, 1970).

The Ventersdorp System is the youngest of the so-called Witwatersrand Triad, a super-system or super-group, consisting of the Dominion Reef, the Witwatersrand and the Ventersdorp Systems (HAUGHTON, 1969). The Ventersdorp era was one of two episodes of sedimentation. The lower volcanic strata rest unconformably upon the Witwatersrand sediments. The lavas of the Ventersdorp System are mainly amygdaloidal andesitic, of a greenish colour, and weather to a fine to medium-grained soil. The amygdaloidal vesicles are often filled with quartz, chlorite, epidote, calcite or chalcedony, the latter often pink or bright vermillion, giving it the appearance of sealing-wax (DU TOIT, 1954).

The Upper Orange River has eroded its streambed through these lavas at several localities in the area between Hopetown and Douglas.

The strata of the Karoo System are almost entirely of continental origin. They cover at present about two thirds of the surface area of South Africa, and have been removed by erosion or buried by later deposits in most of the other parts of southern Africa. In the Upper Orange River area they follow unconformably upon the strata of the older Cape System (Ordovician to Lower Carboniferous). The strata lie horizontally or nearly so, and are exposed subsequently in concentric circles, with the youngest strata in the highest area of the Drakensberg (fig. II.5). They reach their greatest total thickness of 10 150 m (table II.10) in the Eastern Cape Province (DU TOIT, 1954; HAUGHTON, 1969).

The Karoo System is generally divided in four Series, Dwyka, Ecca, Beaufort and Stormberg, partly on lithological and partly on paleontological grounds (table II.10).

At the end of the period in which the strata of the Cape System were formed, the area that presently forms southern Africa was low lying and slightly undulating with very little relief. There was a steady increase in altitude towards the north of the area that at present forms the central part of South Africa. South of 33° South latitude a shallow estuary existed: the Cape Geosyncline. With the beginning of a new geological era the temperature dropped to such an extent, that a glacial period was initiated, the Gondwana glacial period. Ice sheets moved in south and southwesterly directions from the moderate highlands in the present Transvaal covering a huge area of Gondwana land, but probably more than one icecap existed. Striated surfaces (roche moutonnées) on pre-Karoo deposits and tillite, that was originally deposited as ground moraine, are presently found as traces of that glacial period in all parts of former Gondwanaland, including South America, Falkland Isles, Antarctica, southern Africa, Madagascar, India, Australia, Tasmania (DU TOIT, 1954; HAUGHTON, 1969). When temperatures rose and the ice melted away, the land was submerged beneath the ocean, and in a lacustrine environment the

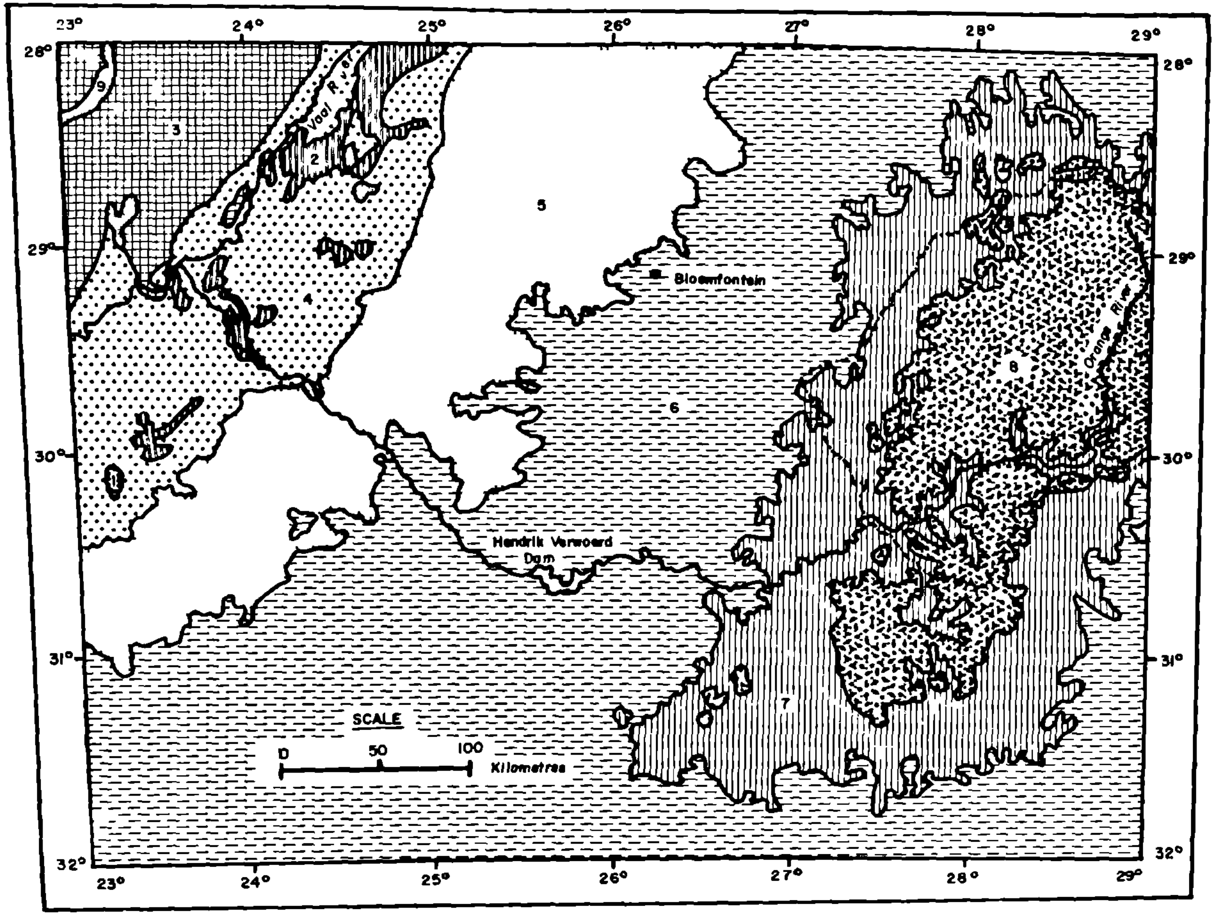


Fig. II.5 Geological map of the Upper Orange River area. 1. Archaean gneiss, etc., 2. Andesitic lavas of Ventersdorp System (Precambrian); 3. Transvaal System (Precambrian), 4-8. Karoo System, 4. Dwyka Series (Upper Carboniferous to Lower Permian); 5. Ecca Series (Permian), 6. Beaufort Series (Triassic); 7. Molteno, Red Beds and Cave Sandstone stages of Stormberg Series (Triassic to Jurassic), 8. Basalts of Drakensberg stage of Stormberg Series (Jurassic); 9. Tertiary to Quarternary deposits (adapted from COERTZE & SCHIFANO, 1970).

TABLE II.10 KAROO SYSTEM (partially after DU TOIT, 1954).

Series	Stages	Max. thickness (m)	European correlation
Stormberg	(Drakensberg Basalts	1 350)	Upper Triassic to Jurassic
	(Cave Sandstone	300)	
	(Red Beds	500)	
	(Molteno Beds	600)	
Beaufort	(Upper	600)	Triassic
	(Middle	300)	
	(Lower	2 750)	
Ecca	(Upper	)	Lower to Upper Permian
	(Middle	3 050)	
	(Lower	)	
Dwyka	(Upper Shales	200)	Lower Permian
	(Tillites	750)	Upper Carboniferous
	TOTAL	10 150	

Upper Dwyka shales were deposited.

In the Upper Orange River area smoothly rounded and striated hummocks of Ventersdorp lava frequently occur, projecting through a mantle of Dwyka tillite, in the area between Hopetown and the Orange-Vaal confluence. They are usually oval, with the striae parallel to the longer axes, and mostly with a clear stoss and lee side, indicating the direction in which the ice moved. Many of these smoothed hummocks have been used by Bushmen and Hottentots during the Late Stone Age for engraving animals and scenes of daily life. Upper Dwyka shales, containing fossils, occur in a narrow zone crossing the Orange River valley just upstream of Hopetown. These shales are fine-grained and lie conformably on the tillite (DU TOIT, 1954; HAUGHTON, 1969; COERTZE & SCHIFANO, 1970).

From a landmass south and east of the present coastline of South Africa Ecca sediments were deposited upon the Dwyka shales in the shallow water of the Karoo Geosyncline. The Lower Ecca deposits consist of greenish shales and sandstones, the Middle of bluish to greenish shales and the Upper of sandstones, mudstones and shales, the latter of which contain coal. In the Orange River area these deposits are relatively thin, due to the fact that this area is far from their sources of origin. Between P.K. le Roux Dam and the neighbourhood of Kraankuil the Orange River flows over Lower and Middle Ecca beds, that lie conformably upon Upper Dwyka shales. Upper Ecca sediments probably do not occur in the area.

At the end of Ecca times a period of desiccation followed which was repeatedly alternated with short periods of flooding. The maximum flooding was probably reached during Middle Beaufort times. The argillaceous and arenaceous Beaufort sediments follow conformably upon the Ecca beds, and are subdivided into Lower, Middle and Upper stages. The Lower stage consists of fine to medium-grained yellowish sandstones alternating with blue, green and occasionally red and purple mudstones and shales. The Middle stage forms a complete ring within the Lower, and consists of red to purple mudstones alternating with bluish and greenish varieties and with bluish sandstones. As a ring within the Middle, the Upper stage is formed by red and maroon mudstones and green and blue shales, containing numerous calcrete concretions. Yellowish fine to medium-grained sandstones also occur. The Beaufort deposits contain many reptilian fossils, silicified wood of the genus *Dadoxylon* and remains of the plant *Schizoneura*. Intrusive dolerite sills and dykes, some of great thickness and extent, are very common in Beaufort beds, and are more abundant here than in Ecca or Dwyka beds (DU TOIT, 1954; HAUGHTON, 1969).

Over a long stretch, from upstream of Aliwal North down to P.K. le Roux Dam, the Orange River flows over Beaufort strata. Between P.K. le Roux Dam and Hendrik Verwoerd Dam these strata are largely of the Lower stage, and further upstream they are of the Middle and Upper stages (COERTZE & SCHIFANO, 1970; HARMSE, 1971).

The beginning of the Stormberg Series is clearly associated with a recrudescence in tectonic activity in the south, from which direction a huge delta fan was formed over the Beaufort surface, laying down conformably, the grey and blue shales and the glittering sandstones and grits of the Molteno beds. The climate at that time must have been cool and wet. Subsequently the tectonic activity decreased and the climate became drier. The fine-grained purple and red mudstones and shales and reddish and yellow sandstones of the Red Beds were deposited upon the Molteno strata. Temperature and aridity kept increasing and this situation culminated in a sandy wind-swept desert, with scattered temporary bodies of water. These desert deposits presently form the third stage of the Stormberg Series, the Cave sandstone. This essentially aeolian, mostly cream-coloured, but sometimes pink or red, fine-grained sandstone weathers in striking shapes, often forming caves, the walls of which in historical times were painted by Bushmen, often with great skill.

At the end of the Karoo era volcanic activity began, first in the form of isolated volcanoes of explosive types, of which the remnants are mainly found in Lesotho, and later in wide-spread outpourings of highly fluid and mobile basaltic lavas from fissures, assuming such proportions that the surface was covered repeatedly over wide areas. The highest parts of Lesotho are still covered with a thick layer of this Drakensberg basalt, which is often amygdaloidal. It ended with the irruption of dolerite magna, forcing its way through the Karoo sediments for some time after the lavas had ceased to pour out over the surface. Presently, evidence of this is given by the numerous concordant or transgressive dykes and sills that have an impact on the relief in the central parts of South Africa. At the end of the Karoo era, which covered a time lapse of a hundred million years, the land was elevated and the Cape orogeny took place in the south (DU TOIT, 1954; HAUGHTON, 1969). Except for a short stretch in the Herschel District, where the Orange River flows over Beaufort deposits, it flows for nearly the entire stretch upstream of Aliwal North over Molteno strata. Just in a few kilometers between the Orange-Telle and Orange-Kornetspruit confluences, the riverbed lies on Red Bed deposits, but the latter frequently form part of the River's valley sides in the area upstream of Sterkspruit. Only in a small area in the Herschel District near Mayaputi bridge occur the Cave sandstone deposits and Drakensberg basalt close to the Orange River. Dolerite outcrops are frequently traversed by the Orange River in the entire sector upstream of

Hopetown (COERTZE & SCHIFANO, 1970; HARMSE, 1971).

The surface geology of the riverbed, based on the map by TRUTER & ROSSOUW (1955), is diagrammatically presented in fig. II.9, showing how the Orange River successively crosses the different Karoo strata and Ventersdorp lavas.

In the lower parts of the Upper Orange River, downstream of P.K. le Roux Dam, red to grey dune sand deposits occur locally. Their age extends back from the Pleistocene well into the Tertiary (Miocene) (DU TOIT, 1954). In the same area local calcrete formations also frequently occur, which often reach a considerable thickness.

Recent alluvial deposits occur virtually all along the bed of the Upper Orange River in a narrow zone. Some of these sandy deposits have subsequently been moved by wind action.

II.4 GEOMORPHOLOGY

Landform is influenced by a number of factors of which the most important are the geological strata in which the landscape is formed, the rate of elevation of neighbouring areas, and the climate under which the landform is formed. Geological strata possess different hardnesses and chemical composition and are thus subject to different rates of mechanical and chemical weathering. The fact that the strata are tilted, folded or lie horizontally has its significance too. If neighbouring areas are elevated to a different extent relative to each other, this will have its impact on the hydrology of those areas, and thus on its erosion pattern. Of utmost importance is of course the climate of the area, in that it influences the weathering and erosion both directly and indirectly. Directly it influences weathering for example through precipitation and insolation, and indirectly it determines the local vegetation, thus having its impact on weathering, chemically and mechanically by root action, and on speed of erosion (STRAHLER, 1960; PUGH, 1966; KING, 1962, 1967; THOMAS, 1965; MEYER, 1966).

KING (1962, 1967) regards the so-called pediplanation cycle as being responsible for the scenic evolution of southern Africa. The dominant operating activities in this cycle are river incision and valley development, scarp retreat and pedimentation, in this sequence. When land is elevated a new cycle of erosion can start, with the incision of rivers (initial stage), developing river gorges and steep valley slopes, that become the dominant units in the landscape (youth stage). The valleys continue to open out, as their sides flatten under weathering, until a relatively stable angle is achieved. Then the valley sides retreat away from the rivers, creating a pediment between these hillslopes and the banks of the rivers. Where the incision of the rivers exceeded the average depth of the weathering profile of the initial erosion surface, the result will be, that two new surfaces are formed, one a stripped surface at a level controlled by the basal surface of weathering, the other a surface formed more slowly by planation of the deeper incised valley sides (THOMAS, 1965). So, at least two surfaces mark the two cycles of erosion, the top one being the oldest and being mainly removed apart from a few small fragments (mature stage). Because of the continued scarp retreat and increasing growth of the pediments, opposing scarps meet from opposing sides of hills and interference between pediments of adjacent drainage basins occurs. Thus, relief decreases and fragments of the initial erosion surface disappear. A multiconcave pediplain landscape is left (old stage) (compare also STRAHLER, 1960). In areas with more rainfall, the pediment becomes straighter in long-profile, and also steeper, than in more arid areas (PUGH, 1966). They are also shorter in semi-arid than in arid areas. In the Karoo they are generally less than 3 km in length from riverbed to the base of the hill side (FAIR, 1948).

From the top of the Drakensberg towards the west all the stages of this pediplanation cycle can be seen: The initial stage on the highest plateaux of the Drakensberg in Lesotho, the youth stage in the deeply dissected area near Sterkspruit and Herschel, the mature stage in the area between Aliwal North and Petrusville, and the beginning of the old stage on the plains west of Hopetown. KING (1967) regards the South African scenery as largely composed of four such erosion cycles, each of them corresponding to a prolonged period of still-stand and erosion after tectonic movements had created new baselevels. Major scarps separate the features of each cycle from those of its predecessor. The surfaces formed by these cycles compare closely with the ones which DIXEY (1942) refers to as peneplains instead of pedeplains (KING, 1967). The oldest cycle of which features still remain, is the "Gondwana Cycle", that created the Gondwana surface. The high plateaux on top of the Drakensberg represent this surface, which was the predominant landscape feature before Gondwanaland broke up to form the various separated parts existing at present (KING, 1962, 1967). WELLINGTON (1958) regards this surface as more likely to be a very greatly worn-down fragment of a formerly much greater mass of basalt, instead of a Gondwana surface of Jurassic age.

From the late Cretaceous until the mid-Tertiary the "African Cycle" followed, producing an extremely smooth surface, from which the present day landscape is carved (KING, 1967). Remains of this "African" surface can still be seen upon the skylines between the headwaters of the major rivers.

During the late Cainozoic two "Post-African Cycles" occurred, of which the land forms cannot be distinguished from each other in all cases. These cycles produced the rolling landscapes that presently are widespread in Africa.

Then followed the Pleistocene upheaval, that resulted in the present plateau form of southern Africa. The edges of the plateau were particularly upheaved and tilted, whereas the Kalahari and Congo Basins lagged behind. Then the present watersheds were created. Erosion of this cycle has only just started (KING, 1967).

An example of a landscape description in terms of the theories by DIXEY (1942) and KING (1962, 1967) is given by BRUCE & KRUGER (1970), who deal with the landscape in the north-eastern part of the Orange Free State, mainly falling into the Caledon catchment area.

Using these criteria of geomorphological history and combining them with the less important criteria of geological structure, climate, location and altitude, KING (1967) divided southern Africa into some eighteen geomorphic provinces. This division compares reasonably well with WELLINGTON's (1946, 1955) regional physiographic classification. Both classifications first distinguish between the interior plateau and the area marginal to the plateau. The Upper Orange River area falls completely into the interior plateau, but is subdivided into two classes, the South African Highveld (WELLINGTON, 1946, 1955) or Highveld (KING, 1967)'and the Cape Middleveld (WELLINGTON, 1946, 1955; KING, 1967), with a common border zone crossing the Orange River in NE-SW direction between P.K. le Roux Dam and Hopetown. KING indicates clearly that the Cape Middleveld runs up the valley of the Orange River from Hopetown in the form of a trough.

The Highveld lies between 1 200 and 1 800 m above sea level and consists largely of extremely broad valley forms incised below the smooth surface of the "African Cycle", which can still be traced upon the major ridges (KING, 1962, 1967). The gradual border between two subtypes of the Highveld, the Basuto Highlands and the Highveld (Karoo formation) lies where the Orange River enters South Africa. Relief is rugged here, but gradually changes towards the west into a wider plain with innumerable kopjes and mesas capped by sheets of dolerite. These outcrops are mainly of the Molteno stage of the Stormberg Series and of the stages of the Beaufort Series. In the Herschel District the Orange River has incised a steep and deep valley into the surface of Red Bed and Molteno strata (fig. II.6a), but from Aliwal North to downstream of Colesberg the narrow streambed of the river lies on a wide pediplain, a feature that is so typical for South Africa (FAIR, 1948; KING, 1967). Near Colesberg, for instance, this pediplain is in the form of a great trough, attaining a width of 50 km (WELLINGTON, 1928). In the entire section where the Orange River flows over the nearly horizontal strata of the Red Bed and Molteno stages and the Beaufort Series the landscape shows many platforms and pseudoterraces, due to weathering of these horizontal strata. Narrow alluvial terraces locally occur along the Orange River over this whole stretch, at about 10 to 30 m above the riverbed (WELLINGTON, 1955). Locally the valley is narrow, where it crosses through a dolerite dyke, as near Aliwal North or a dolerite capped mesa, as near Goedemoed (fig. II.6b). The majority of the transgressive dolerite intrusions have an inclination of between 15° and 50°. Their outcrops thus produce chains of hills, that are marked landscape features over long distances. Sometimes such a chain forms a circle, when the sedimentary layers have eroded away from a large, regularly undulating dolerite sheet (DU TOIT, 1954). The typical sphaeroidal weathering along the joints of the dolerite caps of the kopjes and mesas sometimes cause a columnar structure, and the slopes are always covered with round dolerite boulders of different sizes, which are covered with a brown oxidized layer. The sills and dykes have a strong impact on the movements of underground water (DU TOIT, 1954; HAUGHTON, 1969), thus directly influencing erosion, vegetation and settlement of farmers. Smaller remnants of dolerite dykes, and differences in hardness in the Molteno and Beaufort deposits, cause small local cascades and rapids in the streambed of the Orange River in the entire Highveld region (WELLINGTON, 1955).

Between Colesberg and P.K. le Roux Dam the valley of the Orange River is again deep and steep, carved in the dolerite-capped Beaufort deposits (fig. II.6c).

In the Highveld region clayey surfaces on shale and dolerite outcrops alternate with sandy areas where sandstones prevail, the richest of them being the soils derived from the dolerite. Near the western boundary of the region surfaces of wind-blown sands occur. A more detailed account of these soils will be given in the next section.

At P.K. le Roux Dam the Orange River enters the Cape Middleveld, dominated by what KING calls the "Post-African Cycle" of erosion. This Cycle extends in a narrow trough, sunk

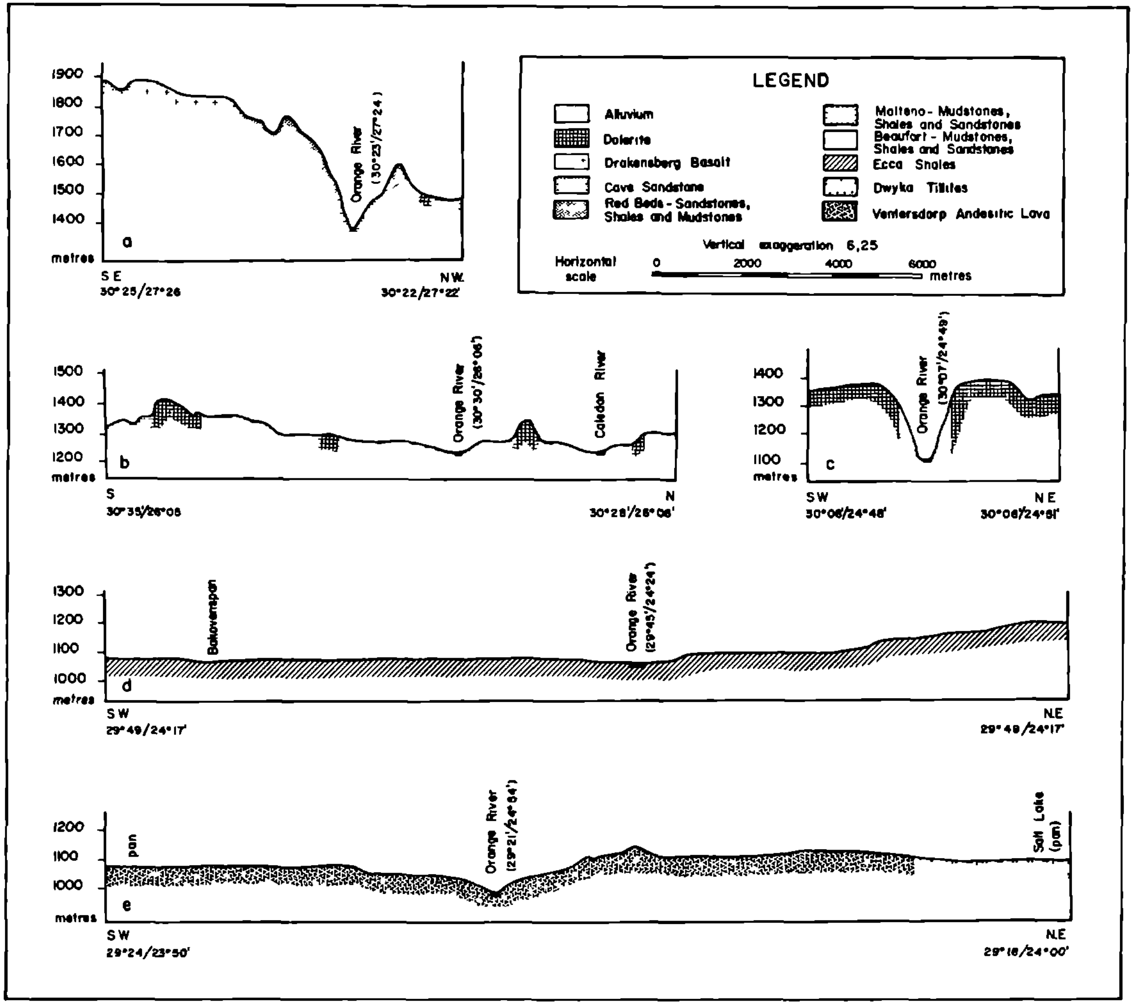


Fig. II.6 Transverse sections through the Upper Orange River valley. The hatchings indicate the surface geology only and not the subterranean disposition of the strata.

well below the Highveld surface and running up the Orange River until the junction with the Caledon (KING, 1962, 1967).

The Cape Middleveld lies mainly between 600 and 1 200 m, and the Upper Orange River area falls in the southern subregion of this geomorphic province (WELLINGTON, 1946, 1955). The area is mainly covered with Ecca and Dwyka beds and has the form of an extensive flat plain, only here and there interrupted by dolerite-capped kopjes and small mesas. The Dwyka tillite leaves characteristic "pebble pavements" on the surface, after weathering. Particularly between P.K. le Roux Dam and Hopetown the bed of the Orange River lies upon a very flat plain (fig. II.6d). Between Hopetown and Douglas the river has carved a somewhat deeper valley with convex sides into the Ventersdorp lavas (fig. II.6e). It is generally supposed that the Upper Orange River in its lowest part between Hopetown and Douglas follows the old drainage lines of pre-Dwyka valleys of a resurrected pre-Karoo landscape (WELLINGTON, 1933, 1955; KING, 1967). Over its entire stretch, but particularly in its middle and lower courses there appear to be a considerable number of land form features suggesting that the process of superimposition has determined the course of the evolution of the drainage of the interior plateau since Jurassic times more than anything else (WELLINGTON, 1955).

Calcrete banks of considerable thicknesses are widespread over the entire area of the Cape Middleveld and numerous salt and calcrete pans occur in the area. A number of theories on the origin of these pans exist. In his extensive account of the Kalahari, PASSARGE (1904) declared zoogenic erosion to be the main agent. During a former pluvial period the area possessed streams and scattered pools. When the climate became drier, the spring-fed pools on the lime-rich rocky plains contained water to which large herds of mammals came to drink. Because of trampling lime-rich mud was developed in considerable quantities and was carried away on hoofs and legs. Aridity increased, and deposition of carbonates from solution because of evaporation hardened the panfloor. Thus, a calcrete pan developed, from which carbonates from then on were only removed in solution with the water drunk by the large mammals. JAEGER (1939) and KING (1967) regard the pans in the southwestern Orange Free State and the Karoo, as being due largely to unequal erosion by wind action. In an initial hollow in the pansandstone under the pan (JAEGER, 1939) water is collected. Because of the arid climate this soon dries up, and owing to the powdery nature of the weathered shales, these soil particles are easily carried away by the frequent, strong whirlwinds. Thus the pan is developed and deepened (KING, 1967). Although WELLINGTON (1945) agrees that pans can be caused by unequal wind erosion, he points out that several pans in the southwestern Orange Free State lie in the form of an interrupted drainage line and were initiated by blocking of the drainage line by means of wind-blown sand. In this way pools were formed, that tended to develop into small pan basins because of the falling-in of the sandy margins of the pools, salt concentration in their floors, owing to capillary movement of underground water and deflocculation and consequent shrinkage of the soil volume. Wind action deepened these hollows. At the head of each pan a reversal of the drainage line and filling-in of the original watercourse beyond the reversed drainage line have taken place, resulting in an isolated pan. GEYSER (1950) considers, that although wind action plays a certain role in the formation of some pans, this is always of minor importance.

According to him virtually all pans are originated by stream capture in flat areas, where old rivers occur, which easily can be disturbed.Because of stream capture silting and the formation of a dam is stimulated due to the lessening of the water volume. In the beginning an outlet still exists. The pan basin is enlarged by silting up to the outlet level and by undermining of the sides. The pan floor is always at the level of the outlet, according to GEYSER. Based solely on the arrangement of pans in the southwestern Orange Free State and the Upper Karoo, GEYSER (1950) produced a map of a supposedly Miocene drainage pattern in this area, showing the Orange, Vaal, and other rivers in the area, occupying positions that differ considerably from their present day courses.

The origin of the vast plains with relief in the form of inselbergs, that are such characteristic landforms for many tropical and subtropical areas, and that are also typical of the Karoo with its numerous kopjes and mesas, has given rise to a number of geomorphological theories. PASSARGE (1904) thought that wind erosion during a Mesozoic desert climate must have been the cause. Others, like BORNHARDT (vide PASSARGE, 1904), who originally described these landforms, consider that repeated marine sedimentation and removal of the sediments by rivers flowing each time in other directions, to be the cause. A recent theory by BÜDEL (1957, 1965), supplemented by MEYER (1966), explains these landforms by means of two related processes: the "Mechanismus der doppelten Einebnungsflächen" (mechanism of double planation) and the "subkutane Seitendenudation" (subcutaneous side denudation). The "Mechanismus der doppelten Einebnungsflächen" states that, because of deep weathering in the tropics and subtropics, the planation process is divided into two spatially and functionally completely separated levels: a lower one, the basal weathering level ("Verwitterungs - Basisfläche"), where the weathering occurs, and an upper one, where removal of material takes place ("Einebnungsfläche" or "Spül-Oberfläche"). Sheet erosion is much more important in this model than river erosion. This erosional "Mechanismus der doppelten Einebnungsflächen" is active up to the foot of the steep relief features by means of undercutting of the sides ("Subkutane Seitendenudation"), thus being responsible for the lateral enlargement of the plains and for the inselberg landscape. These inselbergs, resulting from scarp retreat, are called zonal as against the azonal shield inselbergs (BÜDEL, 1957, 1965). As MEYER (1966) points out, the force of a denudation process is dependant on the efficiency of the transporting medium and the mobility of the material that has to be removed. Hence, not only is the weathering important in the process of pediplanation, but also the vegetation cover, which must be open. This is why in the temperate areas and in the humid tropics with less than two dry months there is not such a pediplanation process as there is in the drier areas. As precipitation in these drier areas usually occurs in heavy showers, resulting in a high run-off, sheet erosion is favoured. Thus, MEYER (1966) concludes that strong periodicity in precipitation and the occurrence of rainfall in heavy showers are of main importance for the efficiency of denudation processes in areas with inselberg landscapes. A low vegetation cover is essential for the removal of the weathered material.

Due to a concentration of water at the base of an inselberg slope as a result of run-off, deep weathering occurs, causing an undercutting of the slope, this keeping it steep. Thus, the pediplain enlarges at the expense of the higher lying areas, according to

BÜDEL (1957, 1965). MEYER (1966) says, however, that the lateral enlargement of the plains is due to an uniform removal of material from the entire slope by way of weathering and run-off. The base of the slope has no special function in this proces. There is a gradation of finer material in the direction away from the inselberg slope, and this causes the concave profile of the transition from pediplain to inselberg slope.

In the Upper Orange River area these features can be observed everywhere.

II.5 SOILS

Soil formation is influenced by rive principal factors: parent material, topography, time, climate and biological activity, of which the first three are passive and the last two are active agents. Parent material is particularly important in respect to the texture of the soil developed from it, whereas topography is primarily important with respect to its thickness, sorting in grain size and leaching. If soil forming processes have acted over a long period upon an initially young soil, it develops a profile and becomes mature. Climate, as an active soil forming agent, is of great importance. Moisture conditions, temperature and wind action all have their obvious influence on soil forming, and so has biological activity (STRAHLER, 1960; SCHEFFER & SCHACHTSCHABEL, 1966). GANSSEN (1957) has emphasized especially the role of climate upon soil formation in his pedogeographical account.

VAN DER MERWE's classification of soil groups of South Africa was published in 1941, and a second revised edition produced in 1962. As it was the only available general map and classification, most more extensive pedological surveys were correlated to this work until recently. Also LOXTON's (1962) classification is partly based on VAN DER MERWE (1962), and so is D'HOORE's (1963) map. The latter work has been used to construct fig. II.9. Towards the end of the sixties a new soils classification scheme was developed for the Tugela Basin in Natal (VAN DER EYK et al., 1969), that at present is being extended to cover South Africa, Lesotho and Swaziland entirely. In this classificatory system soils are grouped in forms and series. Soils having the same kind and sequence of specific diagnostic horizons, belong to one form. By using criteria such as texture, base status, consistency, calcareousness and pH, soils of one form are subdivided into series.

For the Upper Orange River catchment area upstream of Hendrik Verwoerd Dam soils are presently being mapped at a scale of 1 : 50 000 by HARMSE, but information is not yet available, except for minor subcatchment areas (MITCHELL et al., 1971). The soils of the Herschel District have been mapped separately by Aircraft Operating Company (1967). Eleven series belonging to seven forms have been distinguished.

In the area, where the Orange River flows over Molteno and Red Bed strata, the soils fall into the subgroup Highveld Prairie Soils of the Gley-like Podzolic Soils group, according to VAN DER MERWE (1962) (fig. II.7). This subgroup is called Highveld pseudo-podzolic soils by LOXTON (1962) and D'HOORE (1963), and claypan soils by BAWDEN & CARROLL (1968). These soils are mainly residual, although on the steeper surfaces some mixing with colluvial material has taken place. Surface (sheet) erosion and gully erosion is fairly severe in this part of the catchment area, particularly in the Herschel District, which is largely due to poor field management and overstocking.

The zonal soil in this area consists "of a dark greyish-brown to greyish-brown, friable, sandy loam, poor in humus, overlying a grey to light grey, friable sandy clay loam, with an occasional hard iron oxide concretion. Underlying the above is a yellowish-brown, mottled brown, gravelly clay, massive, fairly dense with abundant ferruginous concretions embedded in the soil mass but uncemented, with a foundation of yellowish-bluish-grey, mottled light brown and brown clay, compact, column-like and impervious with scattered iron oxide concretions in the upper section of the horizon" (VAN DER MERWE, 1962). The C horizon consists of partly decomposed parent material. The clay minerals in the A_1 horizon are mainly kaolin, whereas in the B, G and C horizons illite and illite-montmorillonite dominate. The soil is usually acid in the surface layers, but pH increases with depth.

Intrazonal soils occur, where surface drainage is poor and waterlogged or vlei conditions occur. They are "deep dark brown to almost black clays, cloddy in structure, with very little change in texture and structure to a depth varying from 5 to 10 cm, underlain by a soft powdery to concretionary calcium carbonate layer, fairly dense but not cemented, about 45 cm thick" (VAN DER MERWE, 1962). Another intrazonal type is of lithogenic origin. It lies over dolerite from which it is developed. This consists of dark coloured clays and is situated on gentle to fairly steep slopes and on the crests of low ridges with fairly good surface drainage. Often the local phases of this soil type are rather shallow (VAN DER MERWE, 1962).

Very frequent in this part of the Upper Orange River area are the lithosols, which are azonal. Particularly on the steeper slopes, but also locally on the plateaux, soils are very shallow and stony, with gravel and boulders in a wide range of sizes.

West of the Prairie soils area on the Beaufort deposits until the vicinity of Colesberg the Solonetzic group of soils occurs (VAN DER MERWE, 1962; LOXTON, 1962; D'HOORE, 1963) (fig. II.7). These soils consist of "an ashy grey sandy loam, a fairly dense rather porous, structureless mass which breaks up into clods, lumps and finer material on slight pressure. There is only a slight change in colour from the surface downwards. The soils, derived from the maroon coloured shales, preserve a slight purplish tint in the A horizon. The surface layer varies in thickness from 15 to about 25 cm from west to east, depending on the rainfall. This layer contains abundant thin roots. The B horizon is separated from the A by an abrupt transition and consists of dark blackish-brown clay which, on drying, forms columns and when disturbed, breaks up into clods with sides ranging from 3 to 4 cm; the walls of the vertical cleavage planes are lined with colloidal material, darker coloured than the interior of the clods. The roots are irregular, thin and confined to these cracks. This B_1 horizon, which is very impervious to water, when wet, changes gradually into a lighter brown or olive brown colour and a fairly dense, structureless mass which breaks up into clods. The texture, too, changes slightly downwards. Vertical cracks continue into this horizon but are not so prominent as in B_1. This layer varies considerably in thickness from a few to 120 and more cm, depending on

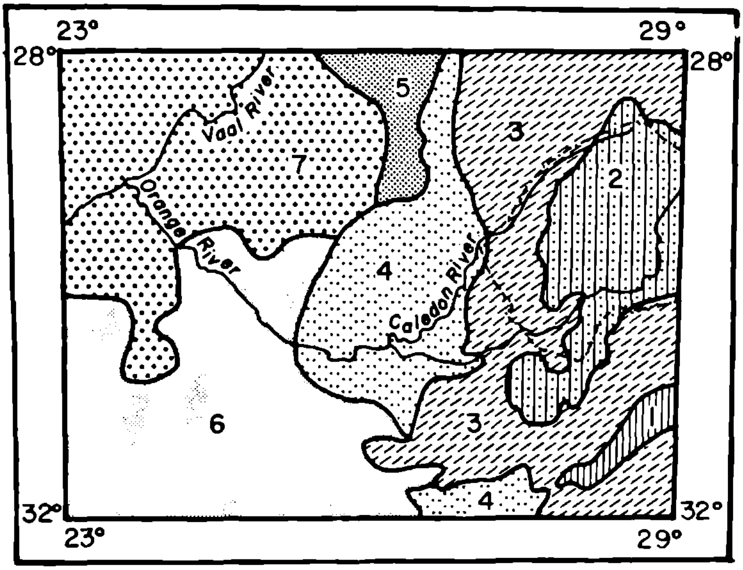


Fig. II.7 Soils map of the Upper Orange River area. 1. Yellow ferralitic soils; 2. Drakensberg black clay soils (lithosolic) and basalt; 3. Highveld Prairie soils; 4. Solonetzic soils; 5. Aeolian sandy soils; 6. Desert soils (mainly lithosolic); 7. Kalahari sand on calcrete (adapted from VAN DER MERWE, 1962).

the situation of the locality. The substratum, has also whitish-brown blotches of soft calcium carbonate and spots consisting of small hard limestone concretions, scattered through the soil mass" (VAN DER MERWE, 1962). Clay minerals are mainly montmorillonite and illite. B horizons are well supplied with adsorbed bases, especially Ca, Mg, K and Na. The reaction of the soils is slightly acid in the A and changing to alkaline in the B horizons. VAN DER MERWE (1962) regards these solonetzic soils as zonal.

In the Upper Orange River area the profile development has not progressed very far, although a definite horizon differentiation usually has taken place.

Sheet and gully erosion are severe in this area and also wind erosion plays an important role, as can be seen from the duststorms, which frequently occur in the area. Again, this erosion is mainly due to poor field management and overstocking and it is at least dubious that its seriousness was "appreciated in time" as stated by ROSS (1965).

The soils derived from dolerite consist of a reddish-brown structureless sandy loam, which breaks into lumps and, on slight pressure, into granules. Underlying this is a compact and slightly columnar, dark reddish-brown clay, with vertical cracks extending into the substratum. When disturbed the soil material breaks into clods of different sizes. The substratum consists of a fairly dense and structureless, reddish brown clay loam, that changes gradually with depth into the decomposing rock. Boulders and gravel are abundant. The dolerite derived soils are mainly colluvial and situated on the slopes of ridges, kopjes of mesas (VAN DER MERWE, 1962).

Along drainage lines, towards the foot of the higher lying areas, intrazonal dark clayey soils, with a poor surface and internal drainage, are found. Lithosols occur locally in this area, too.

The soils in the Upper Orange River area between Colesberg and Hopetown, underlain by Beaufort and Ecca deposits, fall into VAN DER MERWE's (1962) category of Desert Soils (fig. II.7). On the soils map by D'HOORE (1963) a subdivision is made, crossing the Orange River in the vicinity of Skurwekop. The soils in the area between Colesberg and the vicinity of Skurwekop are classified as lithosols and semi-desert soils, and between Skurwekop and Hopetown as lithosols, semi-desert soils and saline, alkali and saline-alkali soils.

Because of low rainfall and more open vegetation in the zone of this soil group, these soils are deficient in organic material and chemical decomposition is less important in their formation, subordinated to temperature and temperature variation. Although the soils are mainly of the lithosolic type, and there is usually not much horizon development in the other soils of this zone, some well developed soil profiles can be found. They consist of a layer of light brown sandy loam, resting on a reddish-brown, fairly dense loam, which is underlain by either hard layers of limestone horizon, or by an extremely hard sandy loam, well cemented by siliceous material, or by undecomposed rock. This undecomposed rock contains calcium carbonate veins and streaks, which have accumulated in the cracks. The clay minerals in the soils near the Upper Orange River are again montmorillonite and illite. Soil pH is over 7,0 and tends to increase with depth. Hard calcrete pans and occasional salt pans occur frequently in the area (Solonchaks). On mountain ridges a light brown sandy soil occurs locally, mixed with rock fragments, and on dolerite hills the soil is very shallow or only in fissures between large boulders (VAN DER MERWE, 1962). Along the rivers and drainage lines sometimes small alluvial deposits occur, here as well as in the other zones of the Upper Orange River. Some wind blown deposits also occur locally in this area.

A more detailed map of the soils in the Upper and part of the Middle Orange River area downstream of P.K. le Roux Dam was drawn by VAN ROOIEN & DOWSEY (1961). The irrigable lands in this area down to Hopetown, were mapped subsequently in detail by BRUWER et al. (1961) and by PELLISSIER (1971). VAN ROOIEN & DOWSEY's map (1961) shows that the soils in the sector between P.K. le Roux Dam and Hopetown are mainly lithosols of different types. Patches of fine red sand of aeolian origin also occur. These sands are those, which are generally referred to as Kalahari sands. Near the Orange River some patches of yellowish-brown, fine to medium, wind-blown sand are found, which the authors regard to have originated from Orange River deposits. Small patches of grey to brown and red brown clay to clay loam of four different series occur in this area too.

The irrigable soils (BRUWER et al., 1961; PELLISSIER, 1971) are divided into classes of practical value, in which deepness of the soil is an important criterion. Eight types, two of alluvial, two of aeolian and four of residual-colluvial and aeolian-colluvial origin were distinguished. The pH values of all these soils are alkaline (between 7,6 and 9,5 and usually about 8,0). Calcrete concretions occur in all these soil types, in the alluvial and aeolian types merely in the lower horizons and through the whole profile in the colluvial types. Calcrete banks are also frequent.

In the last section of its course, between Hopetown and the Orange-Vaal confluence, where the Orange River flows over Dwyka shales and tillite and Ventersdorp lava, the soils fall into VAN DER MERWE's (1962) group of Kalahari Soils, subgroup Kalahari sand on lime (fig. II.7). LOXTON (1962) calls this group Kalahari aeolian sands on calcareous crusts, and D'HOORE (1963) weakly developed reddish-brown soils on calcrete. VAN DER MERWE (1962) points out, that particularly in the marginal zone of the area of this group shown on his map, not only Kalahari sand on limestone is included, but also areas where the calcrete shows on the surface.

The typical soils of this subgroup are of an aeolian origin, namely the Kalahari sand, that has been deposited on the geological strata. In the Upper Orange River area these soils are shallow in comparison with the Kalahari proper. The characteristic horizons of these soils are sand and calcrete, but they do not always occur together, due to factors such as erosion, lack of sand deposits, lime deficit in the underlying rock, or removal of the surface sandy horizon (VAN DER MERWE, 1962).

"The well developed normal soils found in this area consist of a light brown to reddish-brown to brick-red sand, fairly even-grained, coherent, friable well fixed by the roots of vegetation, deficient in humus and varying in thickness from a few cm to about 3 m with little or no change in texture and structure and in many instances in colour. Underlying the sandy horizon of the well developed soil, with an abrupt transition, is found a dirty white to white limestone layer which varies considerably in texture. When exposed on the surface or covered by a thin layer of sand, the surface layer of the B horizon consists of boulder limestone, extremely hard, breaking up into big blocks or boulders.

This layer is always well fissured through which certain vegetation manages to send its roots, probably down to the water table. The thickness of the boulder limestone varies from 30 to 60 cm, underlain by a softer layer, consisting of nodular powdery calcium carbonate mixed; this layer ranges in thickness from 30 cm to several m, passing gradually into the mechanically desintegrated rock mixed with limestone"(VAN DER MERWE, 1962).

The overlaying sand layer holds the rain water, which dissolves the calcium carbonate from the underlying rock and is drawn by capillary action to the surface, where it evaporates, leaving the calcrete bank behind. Therefore, no calcrete layer is formed, wherever the sand deposit is more than 3 m thick and the rain water does not penetrate deep enough to dissolve the carbonate, or where the rainfall is low or the sand layer is too shallow to retain sufficient water (VAN DER MERWE, 1962). Where the calcrete layer is covered with a thick sand layer, it consists of a continuous wavy sheet, that is compact and hard but rather pervious and water percolates fairly easily through it. Sometimes large potholes, filled with loose sand, occur in the calcrete horizon. Near the Orange or Vaal Rivers, these potholes can be filled with diamondiferous gravel, which is patchily deposited in thin layers along the streambeds. The calcrete layer has also been formed in them by an ingrowth from below.

The pH of this soil type ranges from neutral in the surface to strongly alkaline in the B_2 horizon. The clay mineral composition of the Kalahari sand on calcrete consists of montmorillonite, kaolin and illite. These soils are regarded as being intrazonal (VAN DER MERWE, 1962).

On the rocky outcrops in this area, that are not covered by sand, virtually no soil has been formed. The slopes are stone-strewn and the vegetation roots in sandy and loamy fillings of pockets, cracks and fissures in the rock or between the boulders.

In the shallow pans in the area Solonchaks are frequent (VAN DER MERWE, 1962).

VAN ROOIEN & DOWSEY's map (1961) shows that the soils of the area between Hopetown and the Orange-Vaal confluence consists largely of lithosols. Patches of soils of the Petrusburg series are found further away from the Orange River, and near the Orange-Vaal confluence, southwest of Douglas, large patches of aeolian sand occur, which VAN ROOIEN & DOWSEY regard to have originated from Orange River alluvium.

II.6 VEGETATION

Apart from the riverine forest, woodland and scrub, the vegetation of the Upper Orange River area can at first glance be divided into three major physiognomic categories: the grasslands in the area east of Aliwal North, and the xerophytic dwarf shrub types covering the remaining major part of the area, whereas in the section between Hopetown and Douglas an open savanna with trees and shrubs nearly reaches the valley from the north. In describing the vegetation of South Africa most authors have distinguished these main categories.

In his still valuable description of the vegetation of "Das Kapland", MARLOTH (1908) subdivides the vegetation of the Upper Orange River area in three parts: east of Bethulie the short grasslands of the Highveld, with *Themeda triandra* as dominant species, between Bethulie and Petrusville the eastern part of the "Karroide Hochland", and northwest of Petrusville the *Acacia*-steppes of the West Griqualand part of the Kalahari. The eastern part of the karroid Highlands are covered with dwarfshrubs, of which Compositae comprise up to 90 per cent of the species. Especially *Pentzia globosa* and *Chrysocoma tenuifolia* are dominant. Amongst other important species MARLOTH (1908) mentions *Gazania* sp., *Hermannia spinosa, Aptosimum depressum, Gnidia polycephala* and *Lycium* sp.

BEWS (1916) gives a very general account of the vegetation of South Africa in strong Clementsian terminology. He also recognized a grassland, a xerophytic dwarf shrub land and a savanna. Although he regards the eastern grassland and the dwarf shrub steppe of the Great Karoo as formations in the sense of true successional stages, he considers the type of dwarf shrub vegetation in the Upper Orange River area, to which he refers as "Compositae Veld", as "transitional between Karoo and Grassland". His description of this vegetation type is largely based on MARLOTH (1908). Based on a private communication, he also describes the woody riverine vegetation as it occurs near Upington. Early botanists and travellers often refer to this *Acacia karroo* dominated riverine zone, probably because it is so conspicuous, being the only real tree growth in an extensive arid area (e.g. BURCHELL, 1822-24; BRUNNTHALER, 1911).

In 1925 BEWS gave a floristical account of South African vegetation types, emphasizing the relation between growth form, distribution and habitat. Whereas plant succession is towards the mesophytic, the evolution of plant growth forms has proceeded towards the xerophytic, according to BEWS (1925) so that ecological evolution has more or less reversed the order of plant succession. In the progression from grassland through Compositae Veld to Karoo, theplants become increasingly xerophytic. In grassland a growth form occurs, which he calls "associated plants of the grass-veld". This form is adapted to open grassland conditions and has either a vernal or an aestival and autumnal aspect, the latter one being more shrubby. A very great number of the plants belonging to this form with vernal aspect are geophytes or show a tendency to form subterrestrial storage organs. In the proper grassland they are abundant in the early stages of succession but tend to disappear in the later stages, since grass itself has a growth form that is more suitable for climax plant growth in the grassland climatic zone. In the "Compositae Veld" these growth forms "associated with grass-veld" become more prominent, particularly those with autumnal aspect, and in Karoo vegetation they are dominant. The Karoo vegetation shows no succession; "it stops, where it begins", due to climatic factors. These plants of the Karoo, like the xerophytic Compositae, succulents and annuals must be regarded as a recent development (BEWS, 1925).

In spite of their general titles COMPTON's articles (1929a, b) deal only with the winter rainfall Karoo in the southwestern Cape. A lifeform spectrum of this part of the Karoo is compared with those from Death Valley in the U.S.A., the Libyan Desert and Aden showing considerable differences.

POLE EVANS (1936) maps the vegetation of South Africa into twelve types, being subdivisions of the four main types, namely: forest, parkland, grassland and desert shrub. Near

Aliwal North the boundary between the type "short grass" of the main type "grassland" and the type "desert shrub" of the main type of the same name crosses the Orange River. The type "thorn country" of the main type "parkland" never approaches the Orange River in its upper part, according to POLE EVANS' map. The dominant grass of the "short grass" is a dwarf form of *Themeda triandra*, and a number of other grass species are frequent. The uniformity in the general appearance of the vegetation of the type called "desert shrub" is remarkable. The vegetation consists preponderantly of xerophytic, narrowly leaved shrubs and shrublets of fairly uniform height, which are always widely spaced in otherwise nearly bare soil. POLE EVANS (1936) mentions as common species *Pentzia incana, Pentzia globosa, Lycium arenicolum, Chrysocoma tenuifolia, Euphorbia mauritanica, Salsola aphylla, Rhigozum trichotomum, Rhigozum obovatum, Phaeoptilum spinosum*, and others.

ADAMSON (1938) divides the vegetation of South Africa into five main types: sclerophyll, forest, savanna, grassland and semi-desert vegetation. His map shows grassland east of Aliwal North, Karoobush between Aliwal North and Petrusville, and *Gnidia* community from Petrusville to the neighbourhood of Douglas, where this type verges upon bush savanna. Karoo bush and *Gnidia* community are subdivisions of the arid bush type of the semi-desert vegetation. The vegetation in the grassland zone of the Upper Orange River belongs to what ADAMSON calls the dry grassland community, with *Eragrostis, Sporobolus* and *Aristida* species as dominants, although *Themeda* can be dominant locally. *Chrysocoma, Pentzia, Selago* and others are abundant in the driest places, according to ADAMSON (1938). The arid bush type communities consist largely of small xerophytic shrubs, of which many belong to the Compositae, whereas succulents are not very common, as opposed to the succulent bush type communities of the Great and Little Karoo. In the Karoo bush community *Chrysocoma tenuifolia* and *Pentzia* ssp. are by far the commonest. Where salts are concentrated in the top soil species of *Psilocaulon, Lycium* and others occur. In the area between Petrusville and Hopetown the *Gnidia polycephala* community occurs, in which this species is dominant, according to ADAMSON (1938). *Pentzia* and annual grasses can also be abundant. This community grows on deeper soils than the previous one. Near Douglas several communities of the bush savanna type reach the Orange River valley, such as the *Acacia giraffae* savanna and the *Acacia* bush.

A fairly general map of the vegetation of South Africa was prepared by CODD (1952), on which the area east of Aliwal North is indicated as intermediate grassland, the area between Aliwal North and P.K. le Roux Dam as transitional Karoo, and the area downstream of P.K. le Roux Dam as Karoo. This map served as a basis for the A.E.T.F.A.T. map of the vegetation of Africa south of the tropic of cancer (KEAY, 1958).

A most useful general account on the vegetation of South Africa is given by ACOCKS (1953), who distinguishes seven natural main types, four types derived from these natural main types, 70 veld types and many variations and subtypes. A simplified modification based on the map by ACOCKS (1953) was constructed by EDWARDS (1970) and is given in fig. II.8. ACOCKS (1953) based his veld types both on floristic composition and practical utilization, defining them as "a unit of vegetation whose range of variation is small enough to permit the whole of it to have the same farming potentialities". Thus, ACOCKS' classification of veld types provides a suitable basis for land use planning at a regional

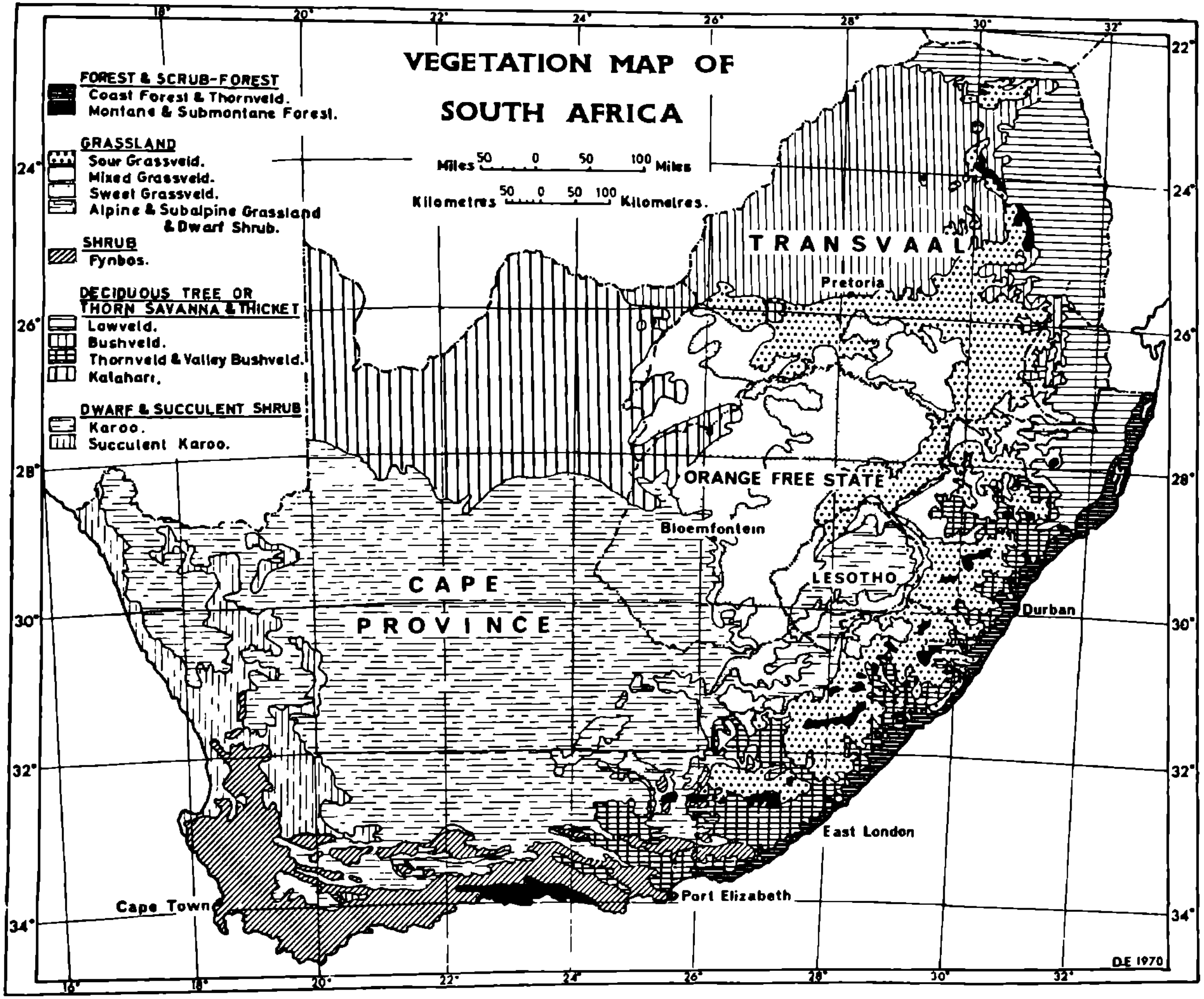


Fig. II.8 Generalized vegetation map of South Africa showing the main floristic-physiognomic types (after EDWARDS, 1970).

scale as well as for the planning of ecological studies (GRUNOW & MORRIS, 1969) and for conservation policy (EDWARDS & WERGER, 1972). The Upper Orange River area comprises altogether ten veld types, of which six actually reach the riverbed. These ten veld types belong to four natural and derived main types and are distributed as given in Table II.11.

Of the sandy *Cymbopogon-Themeda* Veld the portion in the Upper Orange River area belongs to the southern variation. Of this moderately dense, rather short grassveld ACOCKS (1953) lists as general species: *Themeda triandra, Setaria flabellata, Microchloa caffra, Elyonurus argenteus, Heteropogon contortus, Eragrostis chloromelas, Eragrostis racemosa, Eragrostis capensis,* and many others. Patches of *Pentzia globosa, Aster muricatus* and *Aster filifolis* indicate the Karoo invasion in this veld type on eroded places. The *Themeda-Festuca* Alpine Veld, which approaches the Upper Orange River from the east near Mayaputi, is a dense, short grassveld dominated by *Themeda triandra*. Other grass species, such as *Elyonurus argenteus, Heteropogon contortus, Eragrostis racemosa, Eragrostis capensis, Eragrostis curvula* and many others are also common. Temperate grasses, like *Festuca costata, Festuca scabra, Festuca caprina, Danthonia disticha, Helictotrichon longifolium, Koeleria cristata,* etc. are typical for this veld type. In sheltered ravines a scrub occurs for which ACOCKS (1953) lists amongst others the following species: *Leucosidea sericea, Buddleia salviifolia, Rhamnus prinoides, Myrsine africana, Erica caffra,*

TABLE II.11 VELD TYPES IN THE UPPER ORANGE RIVER AREA
(ACOCKS' veld type number in brackets)

Main Type	Veld Type	Locality in Upper Orange River area
Pure Grassveld	sandy *Cymbopogon-Themeda* Veld (48)	upstream from Sterkspruit vicinity
	Themeda-Festuca Alpine Veld (58)	approaching the Upper Orange River valley near Mayaputi
	dry *Cymbopogon-Themeda* Veld (50)	in narrow zone upstream from Aliwal North
False Karoo	False Upper Karoo (36)	from a few km upstream of Aliwal North downstream to P.K. le Roux Dam vicinity
	False Arid Karoo (35)	as False Orange River Broken Veld but outside valley trough
	False Orange River Broken Veld (40)	in Upper Orange River valley from P.K. le Roux Dam vicinity downstream to Salt Lake Pan vicinity
Karoo and karroid Bushveld	Central Upper Karoo (27)	in narrow zone near P.K. le Roux Dam
	Orange River Broken Veld (32)	downstream of Salt Lake Pan vicinity
Tropical Bush and Savanna	Kalahari Thornveld (16)	in small patch north of Hopetown
	Kalahari Thornveld invaded by Karoo (17)	in small patch near Salt Lake Pan

Clutia pulchella, Olea africana and *Celtis africana.*

The southern variation of the dry *Cymbopogon-Themeda* Veld occurs in the Upper Orange River area. According to ACOCKS this variation had formerly a much wider distribution, covering virtually the entire area of the present False Upper Karoo. Due to bad grazing systems, overstocking and trampling this grassveld has been damaged so much that it was replaced by the inferior karroid vegetation reducing the grazing capacity of the veld and favouring erosion (ACOCKS, 1953, 1964, 1966a). Species of general occurrence in this veld type include *Themeda triandra, Tragus koelerioides, Eragrostis chloromelas, Digitaria argyrograpta, Cymbopogon plurinodis, Eragrostis lehmanniana, Helichrysum dregeanum, Eragrostis obtusa, Sporobolus fimbriatus, Cyperus usitatus, Aristida congesta, Aristida curvata, Aristida diffusa* var. *burkei,* and many others (ACOCKS, 1953). The western boundary of these grasslands coincides more or less with that of the pseudopodzolic Highveld soils, as can be seen in fig. II.9. Also the boundary between Stormberg and Beaufort Series and the transitional zone between the warm temperate rainy climate and the arid steppe climate correspond to a certain extent with this boundary between grasslands and False Karoo (fig. II.9).

Over a long stretch, from Aliwal North to P.K. le Roux Dam, the veld along the Upper Orange River bears a vegetation type, that ACOCKS calls the False Upper Karoo ("false" because it was originally grassveld) (see also notes by early travellers below). "The development of this veld type constitutes the most spectacular of all changes in the vegetation of South Africa. The conversion of 20 000 square miles (50 000 km^2) of grassveld into eroded Karoo can only be regarded as a national disaster" (ACOCKS, 1953). Floristically the composition of this veld type, particularly of the plains, is similar to the Central Upper Karoo, the only difference being the abundance of inferior grazing grasses such as *Aristida curvata, Aristida congesta* and *Eragrostis lehmanniana* in the False Upper Karoo. The slopes still carry mainly grasses and some shrubs of which particularly *Rhus erosa* is abundant. The dominant species at present is *Chrysocoma tenuifolia*, a Karoo pioneer. Near the margins with the grassveld the False Upper Karoo vegetation is inclined to be sparser than the genuine Karoo veld types, according to ACOCKS, because, until the grassveld soil has eroded away, the Karoo species have no secure foothold. Harvester termite activity is conspicuous in this area, and can damage the vegetation as severely as the occasionally occurring locust plagues.1)

In the vicinity of P.K. le Roux Dam, the Central Upper Karoo tapers towards the Orange River between False Upper Karoo and False Arid Karoo. This is a genuine Karoo veld type, although grasses like *Eragrostis lehmanniana* and *Aristida congesta* are common. On the extensive dry flood plains *Lycium* spp. and *Rhigozum trichotomum* can be abundant, whereas on the slopes *Rhus undulata* var. *burchellii* is frequent. The aizoaceous species *Eberlanzia spinosa* can be locally abundant. Common species of this veld type and to some

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1) In a coming new edition of his "Veld Types" ACOCKS (pers. comm.) plans to subdivide the False Upper Karoo in a northern and a southern part with the Orange River as a boundary. In the northern part the relic species of the original grassveld are still more frequent than in the southern part.

extent of the False Upper Karoo include *Eriocephalus pubescens, Eriocephalus spinescens, Pentzia globosa, Pentzia incana, Pentzia lanata, Plinthus karooicus, Nenax microphylla, Nestlera humilis, Pegolettia retrofracta, Aster muricatus, Chrysocoma tenuifolia, Salsola glabrescens, Thesium hystrix, Limeum aethiopicum, Gnidia polycephala, Osteospermum leptolobum, Helichrysum lucilioides, Sutera halimifolia, Asparagus suaveolens, Lessertia pauciflora, Pteronia sordida, Eragrostis obtusa, Aristida curvata, Enneapogon brachystachyus, Fingerhuthia africana, Sporobolus fimbriatus*, and many others (ACOCKS, 1953). The western boundary of the Central Upper Karoo - False Upper Karoo corresponds largely with the one between the Beaufort and Ecca Series in the Upper Orange River area and with the transitional zone between the Highveld and Cape Middle Veld physiographic areas.

The False Arid Karoo reaches the Orange River in a narrow zone just downstream of P.K. le Roux Dam. This veld type was originally Central Upper Karoo, but became so completely invaded by elements of the Arid Karoo, that ACOCKS (1953) regards it as separate veld type. Apart from a number of Central Upper Karoo species, the following are important: *Stipagrostis obtusa, Stipagrostis ciliata, Aptosimum leucorrhizum, Aptosimum marlothii, Aptosimum spinescens, Hermannia spinosa, Monechma desertorum, Phaeoptilum spinosum, Monechma incanum*, and others.

Downstream of the narrow False Arid Karoo zone, the False Orange River Broken Veld follows covering the valley trough until the vicinity of Salt Lake Pan. It is rather similar to the eastern variation of the Orange River Broken Veld. Thickets of *Acacia mellifera* subsp. *detinens* and of *Rhigozum trichotomum* occur frequently. *Phaeoptilum spinosum, Boscia albitrunca, Cadaba aphylla* and *Acacia tortilis* subsp. *heteracantha* are common. On ruderal sites *Salsola kali* and *Psilocaulon absimile* can be abundant (ACOCKS, 1953). In the Upper Orange River area the western boundaries of the False Arid Karoo and the False.Orange River Broken Veld and the northern boundaries between these veld types and the Kalahari Thornveld (invaded by Karoo) coincide broadly with the one between the semi-desert and saline soils and the Kalahari sands on calcrete and with the boundary between the steppe and desert climates (fig. II.9).

Further downstream the False Orange River Broken Veld grades imperceptably into the eastern variation of the Orange River Broken Veld proper, the *Acacia mellifera* subsp. *detinens* Veld. Typical trees and shrubs are *Acacia mellifera* subsp. *detinens, Rhus undulata* var. *burchellii, Rhigozum obovatum, Rhigozum trichotomum, Boscia albitrunca, Cadaba aphylla, Phaeoptilum spinosum, Lycium* ssp. and *Grewia flava*. The two typical Orange River Broken Veld/Namaqualand Broken Veld species, *Aloe dichotoma* and *Euphorbia avasmontana* just do not reach the Upper Orange River valley. Other common species in this veld type are *Barleria rigida, Barleria lichtensteiniana, Cyphocarpha angustifolia, Hoodia gordonii, Pteronia mucronata, Lasiocorys capensis, Asparagus suaveolens, Limeum aethiopicum, Cleome diandra, Senecio longiflorus, Nestlera humilis, Polygala asbestina, Aptosimum spinescens, Aptosimum albomarginatum, Monechma desertorum, Hermannia spinosa, Fagonia minutistipula, Cenchrus ciliaris, Cypholepis yemenica, Enneapogon brachystachyus, Enneapogon scaber*, and several others (ACOCKS, 1953).

In the section between Hopetown and Douglas on the righthand side of the river the southern parts of the Kalahari Thornveld and the Kalahari Thornveld invaded by Karoo nearly reach the Orange River valley. The patch of Kalahari Thornveld occurring north of Hopetown is of the central variation of this savanna veld type. Kalahari grasses like *Stipagrostis obtusa*, *Stipagrostis ciliata*, *Anthephora pubescens*, and others, as well as *Themeda triandra* characterize this variation. Other frequent species include *Eragrostis lehmanniana*, *Pentzia calcarea*, *Hermannia comosa*, *Harpagophytum procumbens*, *Aptosimum leucorrhizum*, and many others in the ground layer, whereas *Acacia giraffae*, *Acacia tortilis* subsp. *heteracantha*, *Grewia flava*, *Acacia mellifera* subsp. *detinens*, *Ehretia rigida*, *Asparagus laricinus*, and several others are common amongst the woody emergents (ACOCKS, 1953).

Due to overgrazing, the grassveld of this veld type can be replaced by Karoo, and develop to Kalahari Thornveld invaded by Karoo. According to ACOCKS (1953) *Eriocephalus ericoides* in particular invades on the deeper sand, whereas on rocky hills and on calcrete the main invaders are several species of the Arid Karoo, the Central Upper Karoo and the Orange River Broken Veld.

More detailed surveys than the one by ACOCKS (1953) have not been carried out in the Upper Orange River area as a whole, and such surveys dealing with just a small part of this area or with a part of a veld type that also occurs in this area, are rather scarce. STAPLES & HUDSON (1938) mapped the Lesotho area adjoining the Orange River near the Herschel District as *Themeda triandra* Grassland and from this grassland type derived *Eragrostis* Grassland. BAWDEN & CARROLL (1968) indicate the same area as *Themeda-Cymbopogon-Eragrostis* Grassland, for which they list as the most important species *Themeda triandra*, *Cymbopogon plurinodis*, *Setaria flabellata*, *Elyonurus argenteus*, *Heteropogon contortus*, *Tristachya hispida* and *Eragrostis* ssp.

MOSTERT's (1967) discussion on the veld types of the Orange Free State Region, does not add additional botanical information to that already obtained from ACOCKS (1953).

An exception is formed by the work of HEPBURN (1919), who describes in rather more detail in a non-formal way communities of the Herschel District (called "Formations" by him), indicating the habitats of many species. He makes a main division into "formations of the veld", being the grassland communities of what ACOCKS calls the sandy *Cymbopogon-Themeda* Veld, the "formations of the slopes", being the slope communities in the same veld type, and the "formations of the altitudes above the Cave sandstone", being the communities of the *Themeda-Festuca* Alpine Veld according to ACOCKS.

Two ravine forest associations of the northeastern Orange Free State, which are floristically not directly related, however, though they have a few species in common with communities occurring in the eastern part of the Upper Orange River area, have been described by VAN ZINDEREN BAKKER (1971).

MOSTERT (1958) carried out a detailed analysis of the vegetation near Bloemfontein and Brandfort largely falling into ACOCKS' (1953) central variation of the Dry *Cymbopogon-Themeda* Veld. On physiographic criteria he distinguishes three types of communities: (a) the communities of the valleys, which are comprised of the Valley *Acacia* Bush Community, the *Salsola* Community and the Valley Grass Community; (b) the communities of the slopes, which are comprised of the *Eberlanzia spinosa-Euphorbia mauritanica* Community, the *Euryops sulcatus-Euphorbia mauritanica* Community and other slope vegetation; (c) the grassland communities, which are comprised of the Valley Grassland Community, the *Themeda* Community and the Community on limestone. Floristic analyses of all these communities, according to different methods used for communities of the slopes as against the other communities, are given.

On a karroid spot in the Dry *Cymbopogon-Themeda* Veld, near Bloemfontein, POTTS & TIDMARSH (1937) mapped nine communities recognized in a non-formal way. The two *Euphorbia mauritanica* communities later also distinguished by MOSTERT (1958) were identified in this survey. The various communities were analyzed by means of belt and line transects.

MüLLER (1970) distinguishes in the same veld type near Bloemfontein ten communities, amongst which also the two slope communities described by POTTS & TIDMARSH (1937) and MOSTERT (1958) and two scrub communities also identified earlier by POTTS & TIDMARSH (1937). MüLLER (1970) used Scandinavian School methods in his phytosociological study.

Association analysis was carried out by ROBERTS (1966) on data acquired on a relatively small, physiographically varied area east of Bloemfontein, comprising Thaba 'Nchu, in transitional *Cymbopogon-Themeda* Veld. In this detailed study ROBERTS distinguishes 28 communities, all of which are associated statistically with habitat factors such as slope angle, stoniness and moisture distribution.

On data, partly sampled in the central variation of the Dry *Cymbopogon-Themeda* Veld near Kroonstad, SCHEEPERS (1969) carried out an association analysis and got a large number of groupings, most of which he can interpret ecologically.

A phytosociological survey according to the Zürich-Montpellier method was recently carried out by WERGER (1973a) in False Upper Karoo vegetation of Tussen die Riviere Game Farm in the southern Orange Free State. Several communities were distinguished and preliminarily described, and will be referred to in Chapter VI.

No detailed account on the Karoo or Kalahari Thornveld vegetation in the Upper Orange River area is available, although some studies on the Kalahari Thornveld in its more typical distribution area exist. As early as 1904 PASSARGE gave a general account on the vegetation of the Kalahari. LEISTNER (1967) studied the vegetation of the duneveld of the Southern Kalahari in a non-formal way, whereas LEISTNER & WERGER (1973) carried out a phytosociological analysis of the vegetation of the Kalahari Gemsbok National Park according to the method of BRAUN-BLANQUET. They identified a number of associations that bear close resemblance to communities occurring in the Upper Orange River area.

Since it is generally accepted (DE KLERK, 1947; ACOCKS, 1953, 1964; PHILLIPS, 1956-57; MOSTERT, 1967) that the area now covered by False Upper Karoo was still grassveld not so long ago, and that the areas now covered with False Arid Karoo, Central Upper Karoo, False Orange River Broken Veld, Orange River Broken Veld and Kalahari Thornveld invaded by Karoo were previously also much grassier, with far less extensive scrub cover of *Acacia mellifera* subsp. *detinens* and *Rhigozum trichotomum*, it is interesting to see what the early travellers reported from these areas.

Sir John BARROW (1801) travelled in 1798 northwards along the Seekoei River, just east of Colesberg, until its confluence with the Orange River. He then travelled for five days upstream along the Orange River and turned southwards again. On his map he marks at a position near the present Colesberg, "Fine meadows well clothed with grass...", and slightly to the south of this locality "Excellent grazing country but much in fested (sic) with locusts". In his journal (1801) BARROW states:-

> "....we proceeded about twenty miles to the northward over a flat surface of country, consisting chiefly of meadow-ground, well watered by numerous springs and small rills, but destitute of every appearance of a bush or shrub. On every side were grazing a multitude of wild animals, as gnoos, and quachas, and hartebeests, and springboks, in such large troops as in no part of the country had before been observed. The place of our encampment was called Gordon's Fonteyn [south of Colesberg, near Andriesfontein], and near it stood the last Christian habitation, towards this quarter of the colony." (p.253).
>
> "....at the distance of a couple of miles on the south side [of the Orange River], were plains well covered with herbage". (p.297).
>
> "On the fifth day we left the river, and, turning off to the southward, travelled over a flat country of a strong clayey soil, well covered with fine grass, but destitute of wood or bushes, and ill supplied with water". (p. 301).

Andrew SMITH travelled in 1834-1836 with his expedition from Graaff-Reinet via Colesberg, Philippolis and Bethulie to the present northeastern Orange Free State area and Lesotho, turned back to Philippolis, travelled up to Griquatown, the Limpopo and the Transvaal and returned to Graaff-Reinet via Griquatown and the present Hopetown. In his diary he writes (KIRBY, 1939) about the country near Gordon's Fontein:-

> "The country over which we travelled was almost destitue of vegetation: only thinly covered by dwarf black bushes of from six inches to a foot in height. Towards the centre of the flats patches of coarse grass and rushes occurred here and there". (Vol. 1,p. 62);

and near Colesberg:-

> "The face of the country exhibited a most barren appearance, nothing green to be seen; any grass that existed was dry and withered [because it was winter when SMITH travelled there]. The short bushes were all in the same condition, so that it is quite impossible for cattle or sheep to procure even a sufficiency to support existence. ....[The white farmers] intend purchasing wool sheep with the compensating money [for release of the slaves], the prejudice against them having quite disappeared in the Graaff Reynet district. They remark that the country they inhabit is not calculated to support the large troops of African sheep which they possess, but they think it would sustain sufficient wool sheep to enable them to live comfortably". (Vol. 1, p.63).

The border of the Cape Colony was in those days formed by the Orange River. On the vegetation north of the Orange River near Philippolis SMITH remarks (KIRBY, 1939):-

> "....the old grass stood rather more abundant" (Vol. 1, p.79);

and

> "on flats, but especially on the hills, an abundance of dry grass" (Vol. 1, p.81);

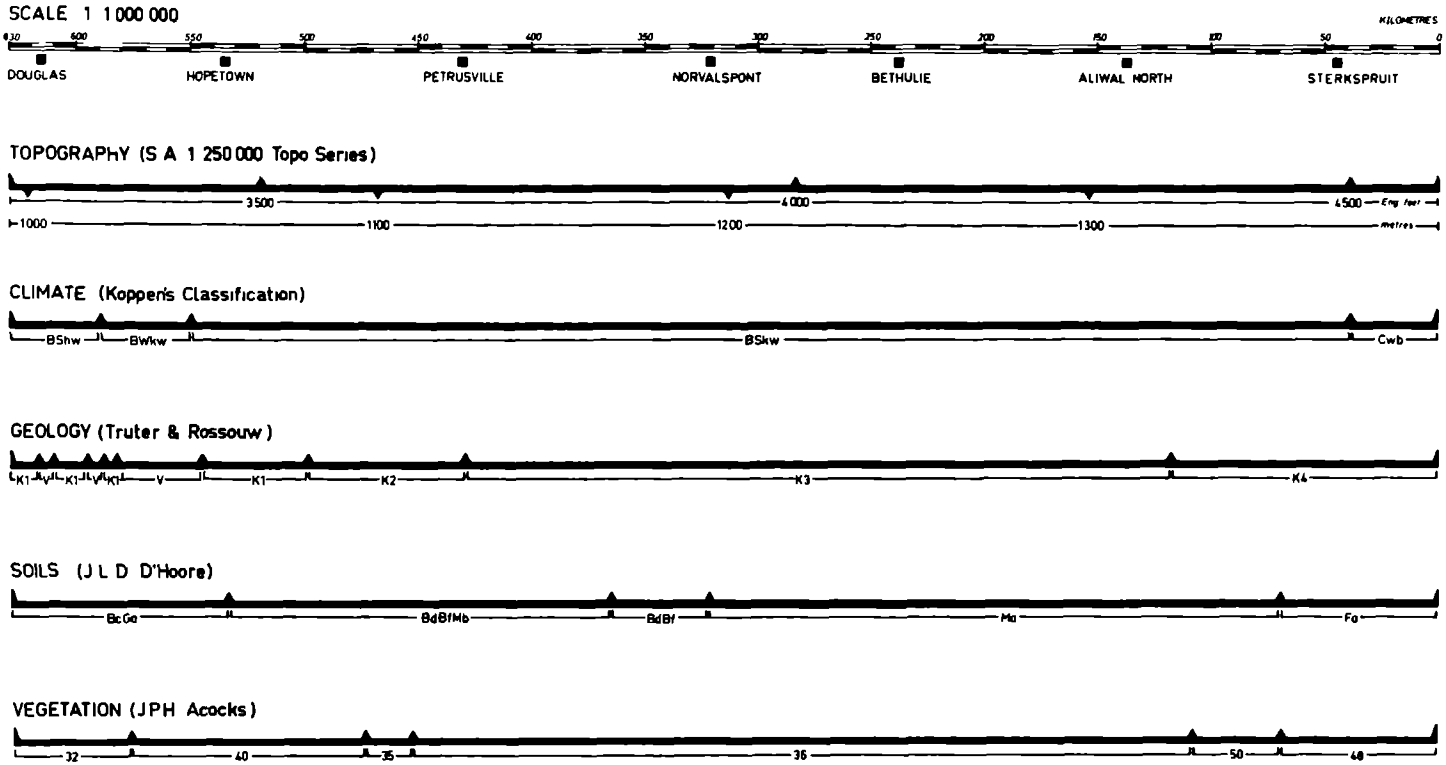
and near Bethulie:-

> "the road extended across five flats covered with a little dry grass. Almost no bush" (Vol. 1, p.84);

and:-

> "The flats have scarcely a bush upon them, and the grass grows in tufts closely set together. There are two sorts of grass occurring, both sour and sweet grass. The latter is the most abundant. The grass on the hills is also said to be sour.

UPPER ORANGE RIVER (DIAGRAMATICALLY)



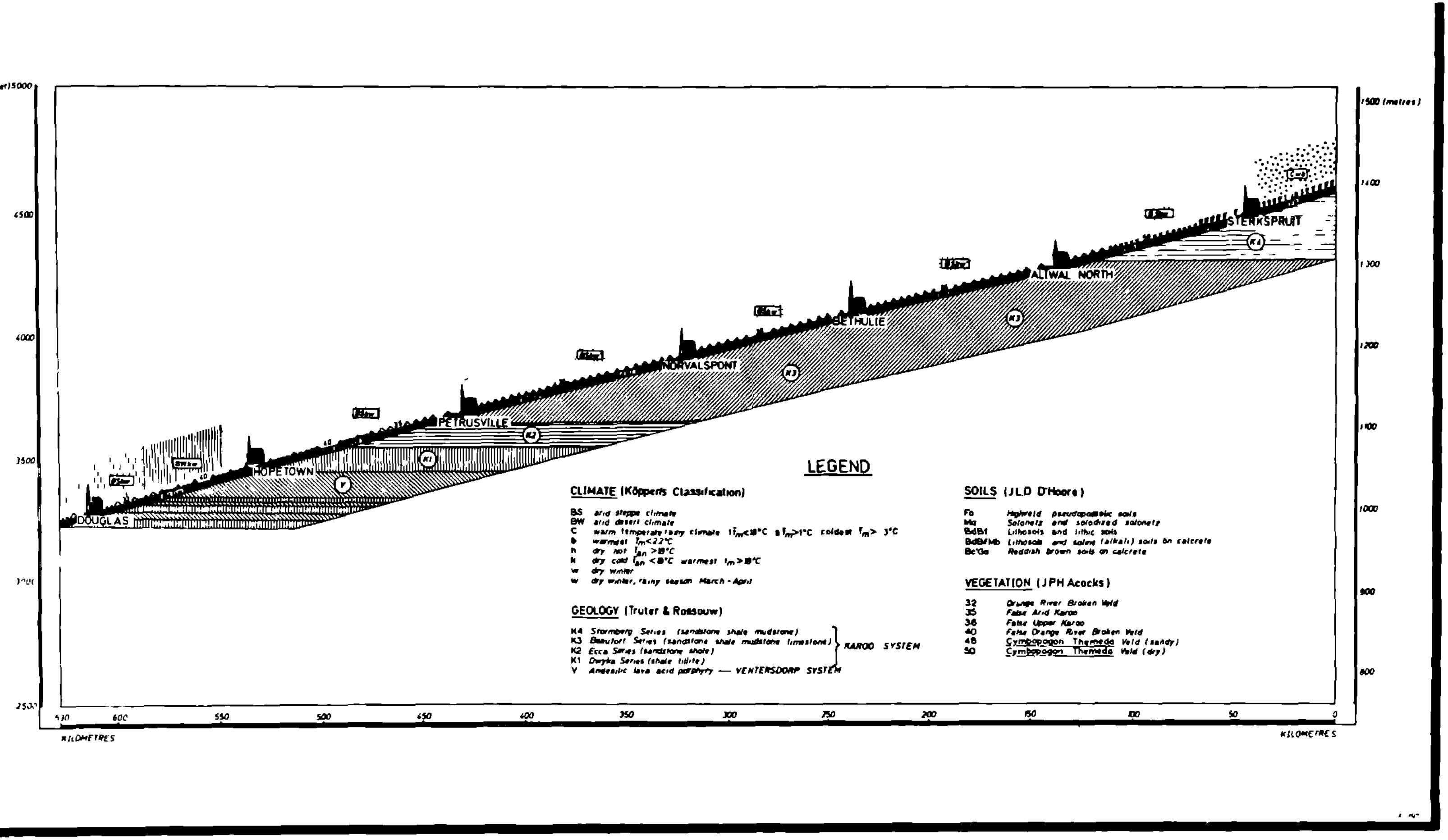


Fig. II.9 The Upper Orange River diagrammatically comparing altitudinal, climate, geological, soils and vegetation gradients.

> Amongst the rocks on the sides and tops of the hills a few stunted trees and bushes". (Vol. 1, p.89).

SMITH makes many more remarks on the abundance of grass in these areas.

COLLINS, who lived for a while north of the Orange River, writes (COLLINS, 1965), that in 1849 the veld in the vicinity of Smithfield contains "thousands of broad acres of good and wholesome pasturage for all kinds of live stock, ..." (p.11). Also CASALIS (1933), without refering directly to the vegetation, reports on the huge herds of antelopes in the àrea at that time, indicating that the grazing value of the veld must have been good.

From these reports, it is clear, that at the end of the eighteenth century the veld near the present Colesberg, then outside the borders of the Cape Colony, had an abundancy of grass. Thirty fivè years later, after the border had been formed by the Upper Orange River for a period of ten years, this vegetation had been destroyed and replaced by dwarf shrub. In the area north of the Orange River, not yet included in the colonized areas, grassland was still the dominant vegetation type.

Further downstream Hinrich LICHTENSTEIN crossed the Gariep (Orange River) in the early nineteenth century at a place called Priskab (Prieska) on his travels from Cape Town to the vicinity of Griquatown. He reports (LICHTENSTEIN, 1811-1812) from this area, that "ganze ausgedehnte Flächen waren mit langem Grase bewachsen, ..." (Vol. 2, p.389). South of the Orange River in this area he observed also *Rhigozum trichotomum* occurring in larger patches, and *Acacia mellifera* subsp. *detinens* scrub:-

> "Der grösste Theil des Gebüsches bestand aus einem Strauch mit gefiederten Blättern und starken rückwarts gekrümmten Dornen (leider ohne Blüthen und Früchte) in welchen sowohl ich als mein Hottentott hängen blieben, ... Nur mit grosser Mühe und mit zerrissenen Kleidern machten wir uns los ....Dazwischen standen mehrere Arten von *Lycium* und *Cestrum*, ..." (*Phaeoptilum* (?)) (Vol. 2, p.360).

In 1811 William BURCHELL travelled more or less the same route and also reports *Acacia mellifera* subsp. *detinens* (BURCHELL, 1822-1824):-

> "The largest shrubs were about five feet high, a plant quite new to me, but well known to the Klaarwater people [Griquatown], by the name of Haakedoorn .... I was preparing to cut some specimens of it; which the Hottentots observing, warned me to be very careful in doing so, otherwise I should certainly be caught fast in its braches. In consequence of this advice, I proceeded with the utmost caution, but, with all my care, a small twig caught hold of one sleeve. While thinking to disengage it quietly with the other hand, both arms were seized by these rapacious thorns, and the more I tried to extricate myself, the more entangled I became; till at last it seized hold of the hat also; and convinced me that there was no possibility for me to free myself, but by main force, and at the expense of tearing all my clothes. I therefore called out for help, and two of my men came and released me by cutting off the branches by which I was held. In revenge for this ill-treatment, I determined to give to the tree a name which should serve to caution future travellers against allowing themselves to venture within its clutches. *Acacia detinens* Burchell." (Vol. 1, p.309-310).

Later GRISEBACH (1872) repeated this story, and MARLOTH (1887) commented upon it, thereby reducing the reputation of danger of this shrub. Proceeding on his journey from Priskab (Prieska) to Klaarwater (Griquatown) and from there to the confluence of the Ky-Gariep (Vaal River) and the Nu-Gariep (Orange River), BURCHELL reports on a variety of plants he collected and tells of how the Bushmen had burnt the grass, because the fresh green new grass would attract game. Somewhat further to the south he reports large grass covered plains with scattered trees which he describes (*Boscia albitrunca*). He also reports on plains with *Rhigozum trichotomum* and "delightful pastures" (Vol. 2, p.35). In 1813 BURCHELL traveled back from Latikuun (near the present Kuruman), Klaarwater, along the Upper Orange River towards the present Hopetown and Colesberg, but his journal does not report on this trip.

Andrew SMITH, on his way back from the present Griquatown along the Orange River towards the present Hopetown and Graaff-Reinet, in 1836, says (KIRBY, 1939) that he found near Hopetown "fine grass", particularly on the slopes (Vol. 2, p.294-295).

It may be concluded that although the shrubs *Acacia mellifera* subsp. *detinens* and *Rhigozum trichotomum*, at present covering such extensive areas, occurred in the area in those days, they were not as preponderant, and plains covered with grasses were a regular feature of the landscape.

The disappearance of these grasses and the encroachment of bush and dwarf shrub has been ascribed to overstocking, particularly of sheep, followed by trampling and overgrazing (SHAW, 1875; MARLOTH, 1908; STAPLES & HUDSON, 1938; DE KLERK, 1947; ACOCKS, 1953, 1964; BAYER, 1955; PHILLIPS, 1956-57; VOLK, 1966b; MOSTERT, 1967; GIESS, 1968). These authors say, that because the sheep graze the palatable grass species selectively and heavily, these plants die. On the bare spots the unpalatable bushes can establish themselves, and once present, can grow vigorously because the sheep will not touch them until no grass or other palatable species are left. Trampling has the same effect in that it damages the weaker, shallow rooted grasses more than the dwarf shrubs and shrubs. ACOCKS (1966a) has recommended a particular grazing system, in which many smaller camps are grazed intensively over a short period, followed by a longer period of rest. In this way ACOCKS expects the original grassveld to regenerate.

WALTER (1939, 1962) does not discuss this grazing factor for the False Upper Karoo area, but regards factors in soil type and moisture distribution of great importance in the present mosaic of shrub, dwarf shrub and grass. For the zonal savanna regions (WALTER, 1954a), which include also the vicinities of Douglas, he discusses the bush encroachment in ecophysiological terms in a number of publications (WALTER, 1939, 1954b, c, 1962; WALTER & VOLK, 1954). This savanna is, according to WALTER, an equilibrium between grasses and woody plants, in which the grasses are in the majority. Because of grazing and trampling the relative quantity of the grasses gets reduced, which means, that the total quantity of water used by them will be less. Thus, at the end of the rainy season more water remains in the soil, which can be used by the woody plants. These woody plants increase vigorously, and with continued grazing this process is cumulative in favour of the woody plants.

Palynological studies of cores taken at Aliwal North dating back to between 12 600 ± 100 and 9 650 ± 100 BP, and at Florisband near Bloemfontein, of which the oldest pollen preserved in the bottom layers are more than 48 000 years old, revealed that karroid and grassland vegetation alternated several times at these localities over this period of time. The alternations in vegetation were associated with changes in temperature. The cooler and more humid periods are represented by the grassveld and the warmer and drier conditions by the karroid vegetation. These cooler periods could be correlated preliminarily to Riss and Würm glaciations and the Allerød Interstadial in Europe (COETZEE, 1967; VAN ZINDEREN BAKKER, 1969b).

II.7 LAND USE

Differences in climate, vegetation, topography and soils correspond with considerable differences in agricultural land use (compare UHLIG, 1965), but by far the main form of land use in the whole of the Republic of South Africa, and particularly so in the Upper Orange River area, is extensive farming (TOMLINSON, 1970; EDWARDS, 1972; EDWARDS & WERGER, 1972). For the Upper Orange River area this is clearly shown by the classifications in natural farming regions according to PENTZ (1949), the Afdeling Ekonomie en Marke (1951) and the Kommissie van Ondersoek (1970), which are similar in their main divisions of the area. PENTZ (1949) calls the area east of the vicinity of Aliwal North the intensive farming region of mixed character: stock farming and arable production are both main sources of income. West of the Aliwal North vicinity lies the semi-intensive and extensive farming region, in which sheep and cattle farming are the main sources of income. Also on the map of the Afdeling Ekonomie en Marke (1951) a main boundary traverses the Upper Orange River area in the vicinity of Aliwal North, east of which lies the mixed farming region and west of it the sheep farming region. The map of the Kommissie van Ondersoek (1970) shows that east of Aliwal North the Orange River virtually forms the boundary between the natural farming regions C_1 (Mixed Farming Region of the southeastern Orange Free State) on the righthand side of the river and D_2 (South Drakensberg Grazing Region) on the lefthand side of the river. The western boundary of these two areas is formed by the 500 mm isohyet and coincides broadly with ACOCKS' boundary between grassveld and False Upper Karoo. West of this boundary lies the Extensive Small Cattle Region, subdivided into an Eastern (F_1) and Central (F_2) part with a common boundary in the Upper Orange River area from De Aar via the vicinity of Hopetown towards Douglas. In the C_1 region farming consists mainly of crop production (maize, caffir corn, peanuts and rye) and stock farming. The considerable number of farms of a subeconomic size in this region form a serious problem. In the D_2 region cattle and sheep farming on natural veld is the main practice. The carrying capacity of the grasslands in the C_1 and D_2 regions in the vicinity of the Orange River is about 1 to 2,5 hectares per beast or per 7 sheep (RATTRAY, 1960). In the F_1 and F_2 regions mainly extensive farming with merino sheep is practised for wool and mutton production. The carrying capacity is here 1 to 2,5 hectares per sheep (RATTRAY, 1960). In the F_1 region horse breeding is also important (Kommissie van Ondersoek, 1970).

In the grassveld area east of Aliwal North (C_1 and D_2 region) deterioration of the natural veld, in the sense of encroachment of Karoo bushes and erosion of the top soil, is serious (IMMELMAN, 1967; Kommissie van Ondersoek, 1970). It is generally accepted that mismanagement of the veld through overstocking, trampling and incorrect grazing systems are the main causes for this situation, as already mentioned above. Social and economic factors also play an important role in the continuity of this deterioration process (IMMELMAN, 1967; ROBERTS, 1968). In a detailed scheme ROBERTS (1965) shows how this mismanagement of the veld leads to an ultimate decrease in productivity by a sequential process. Veld burning is regarded at least partially as an ancient and natural factor in the ecology of the South African veld (BAYER, 1955; PIENAAR, 1956; KILLICK, 1963; WALTER, 1968; SCOTT, 1970) and is reported to have favourable effect on the eradication of Karoo bushes in the grassveld of Lesotho (STAPLES & HUDSON; 1938). Others, however, (e.g. PIENAAR, 1956) have warned against the use of fire in veld management. Alternatively, improved grazing systems have been recommended for reclamation of more valuable pastures in the areas invaded by Karoo bushes (STAPLES & HUDSON, 1938; TIDMARSH, 1947; ACOCKS, 1966a). In the False Upper Karoo area some farmers have experimented with sowing of *Eragrostis curvula* after ripping of the surface soil. Paricularly in the Herschel District the veld is in a very poor condition (Aircraft Operating Company, 1967). Since the quantity of cattle rather than its quality is still an important status determining factor in this native society, the problem of overstocking remains difficult to solve here.

Cultivation of crop plants is practiced only on a limited scale in the Upper Orange River area. In the Herschel District maize, kaffir corn and other cereals, vegetables and fruits are grown on small fields by the local native population. Small areas are also afforested with *Eucalyptus* which is utilized as fuel. *Opuntia* is planted too, to serve as additional cattle and sheep fodder.

Also in the remaining part of the Upper Orange River area *Opuntia* is grown for the purpose of additional fodder, although the cultivation of lucerne under irrigation on the narrow zones of alluvial deposits along the riverbed is a more common practice. Usually the riverine forest, woodland and scrub is cleared for this purpose. Just upstream of Hopetown this riverine zone under cultivation is wider and cotton crops are grown there. Also near the Orange-Vaal confluence a wider zone is under cultivation, in particular along the Vaal River.

An area comprising about 30 000 ha in all and consisting of three reserves is devoted to nature conservation in the Upper Orange River area. The reserves are the Tussen die Riviere Game Farm at the Orange-Caledon confluence (about 23 000 ha), the Orange River Fisheries Station at Oviston (2 580 ha) and the Rolfontein Nature Reserve at P.K. le Roux Dam (5 200 ha), all preserving False Upper Karoo vegetation (EDWARDS et al., 1971; EDWARDS & WERGER, 1972). Besides nature conservation these areas are also used for recreation, as is the large Hendrik Verwoerd Dam reservoir.

Data on the area in use by urban settlements and transport purposes in the Upper Orange River area are not available, but these areas are not extensive.

An interesting feature in the area near Philippolis, where the Orange River flows through a deep, steep sided valley is that the farms here have all got a narrow path down the valley side to the river. In the olden days this path was mainly used to collect *Osyris lanceolata*, which grows on the steep valley sides, and whose bark was used for the tanning of skins and leather. The local farmers took its bark to Philippolis in order to obtain ready cash to buy those goods, which they could not provide for themselves.

II.8 CONCLUDING REMARKS ON THE PHYSIOGRAPHY OF THE AREA

The overriding physiographical feature amounting from this description of the Upper Orange River area is that of a gradient in the direction of the rivercourse. From where the Orange Rivers enters the Republic of South Africa down to where it is joined by the Vaal River, there is a steady decrease in altitude and in relief, an increase of desert conditions, an increase in xeromorphic structure in the vegetation types from grassveld to open karroid dwarf shrub, a stepwise change from the strata of the uppermost series of the Karoo System to those of the lowest, a change from pseudopodzolic soils via solonetzic to desert soils, from a mixed farming region with stock and arable farming to a region with stock farming on an extensive scale. Still, it is possible to divide the area into three more or less clearly defined subunits on the basis of eco-geographical characters (fig. II.9):

(1) the high lying, dissected area east of Aliwal North, with a temperate tropical climate, the geological substrate consists of Molteno, Red Bed and Cave Sandstone strata, the soils are largely pseudopodzolic, the vegetation consists mainly of grassland, and the land use, is mainly of the mixed farming type;

(2) the long middle area from Aliwal North to P.K. le Roux Dam, with a drier and hotter steppe climate, less relief, on Beaufort strata, with solonetzic and desert soils, False Upper Karoo dwarf shrub and grass vegetation, and semi-extensive to extensive stock farming;

(3) the lower lying, mainly flat area west of P.K. le Roux Dam with a sub-desert climate, where the geological substrate is formed by the Ecca and Dwyka Series of the Karoo System and by the Ventersdorp lavas, with several pans, largely with lithosols and sandy Kalahari soils on calcrete, mainly genuine Karoo vegetation types, and where only extensive stock farming, primarily with sheep, is practiced.

II.9 HISTORICAL NOTES

One hundred and sixty four years passed after Bartolomeu DIAS on the 6th June 1488 discovered and named the Cabo de Boa Esperanza, before the Vereenighde Oostindische g'octrooijeerde Compagnie decided to establish there a revictualling station under Jan VAN RIEBEECK to supply its ships en route to the Far East with fresh water, meat and vegetables. During the following century some exploration was undertaken into the interior, and some early settlers freed themselves from the authority and rule of the Vereenighde Oostindische g'octrooijeerde Compagnie and started farming outside the borders of the early colony.

During his travels of 1761-62 Hendrik HOP was the first European to reach the Orange

River in Namaqualand and he referred to it as the Groote Rivier (FORBES, 1945). During 1772-1776 the Swede SPARRMAN travelled in the Cape colony and although he did not reach the Orange River, he heard from Hottentots of the great river north of the Sneeuberg near Graaff-Reinet, that rose in the east and thereafter took a straight northward course. SPARRMAN, however, related the great river from these stories with the Groote Rivier that was reached and crossed earlier by Hendrik HOP in Namaqualand (FORBES, 1945).

Probably on the 23rd December 1777 Robert Jacob GORDON reached the Orange River near the present Bethulie and gave it its present name, herewith becoming the first effective discoverer of the Orange River north of the Sneeuberg (FORBES, 1949). R. J. GORDON was a Dutchman of Scottish extract, who came to the Cape Colony as a military captain in the Dutch garrison there, later to be promoted to its commander. He called the spot where he reached the Orange River "De Fraaye Schoot", probably referring to good shooting of hippopotami there. He drew a wide panorama of the scene (fig. frontispiece) and described the country as all grassland and inhabited by Bushmen and Hottentots. Ten months later GORDON accompanied Governor VAN PLETTENBERG on his travels into the interior during which they came to within a distance of 50 km of the Orange River in the vicinity of the present Colesberg, where VAN PLETTENBERG erected his beacon. There is strong evidence that GORDON withheld information from VAN PLETTENBERG on the position of the Orange River he had reached the year before, in fear that the Governor would name the river after himself, whereas GORDON wanted it to bear a name in honour of the Prince of Orange. In 1779 GORDON accompanied by the Englishman PATERSON travelled to the mouth of the Groote Rivier in Namaqualand, where he named it again Orange River. GORDON travelled then upstream along the Orange River until the vicinity of the present Prieska in order to ascertain if it was the same river he had reached at "De Fraaye Schoot", whether it was navigable, to see the Aughrabies Falls, about which he had heard rumours, and to ascertain the exact course of the river (FORBES, 1948, 1949).

By 1825 the colonists had settled on the major part of the area south of the Upper Orange River, which was then proclaimed the official border of the Cape Colony. Nomadic habit of life among the pastoralist farmers was rather common in this area of the Colony (CLARKE, 1930). The area north of the Upper Orange River was inhabited by Sotho tribes in the very east and by Bushmen, Hottentots, Griquas and Corannas in the remaining part. Philippolis was the Griqua capital in those days, and near the present Bethulie lived a small refugee Bechuana tribe. Andrew SMITH reported in 1834, that the white farmers regularly crossed the Orange River from the south with their sheep to let them graze temporarily on the grasslands north of the Orange River, those south of it already being destroyed and bare or covered with Karoo bushes. This frequently caused serious frictions between these farmers and the Griquas (KIRBY, 1939).

Incursions by the white "trekkers" across the Orange River and onto the eastern plateau assumed great importance with the Great Trek of 1836, following the route over the watershed between the westward flowing rivers and the Caledon (CLARKE, 1930). This resulted in the establishment of the independent Afrikaner Republics north of the Cape Colony, and after many complications at the turn of the century, ultimately in the proclamation of the Republic of South Africa (1961).

Towards the end of the nineteenth century and the beginning of the twentieth, water was pumped out of the Great Fish and Sundays Rivers in the Eastern Cape for irrigation purposes. Dams were constructed locally to provide for a regular distribution of water over the year, but run-off from the catchment areas proved to be inadequate for proper irrigation of the areas and thus for a prosperous economic development. Thoughts went in the direction of diverting the water from the Upper Orange River towards the Great Fish and Sundays Rivers by means of an 80 km long tunnel, a plan, proposed by the Director of Irrigation in 1928. Lack of financial means made this proposal impracticable (ALEXANDER, 1966).

By 1903 WILLCOCKS had already proposed a plan for building a high diversion weir at the Vanderkloof site, where at present the P.K. le Roux Dam wall is under construction, in order to irrigate land as far downstream as Prieska.

In 1928, LEWIS discussed the future development of the Orange River and came to the conclusion that large storage dams had to be constructed, to provide water for irrigation as well as to control the devastating floods, that occurred periodically. This and similar ideas appealed to the settlers in the Lower Orange River area, and a number of proposals were worked out to develop the Orange and Great Fish - Sundays Rivers areas. Apart from the demands of the farmers in the respective areas, the municipalities of the major urban centres in these areas demanded an increase in their water resources and developing industries created a demand for electric power, which could be generated by hydroelectric stations. Ultimately, this enabled the formulation of a comprehensive development plan for the Orange River, which provides for the requirements of irrigation, urban water supply, hydro-electric power development and flood control. The plan will be developed in stages and comprises a huge storage dam near Norvalspont, an 83 km long tunnel from Oviston to a Great Fish River tributary, a shorter second tunnel from there to the Sundays River, a high storage dam near Petrusville to provide irrigation water in a large area further downstream, and a third dam at Torquay for similar purposes. In 1961 these proposals were approved by Parliament and in the following year a start was made with the construction of the Hendrik Verwoerd Dam and the Orange-Great Fish Rivers tunnel (ALEXANDER, 1967a, b). In September 1970 the dam wall was closed and the water started damming up behind the wall. After exceptionally good rains in the Upper Orange River catchment area in the 1971-72 season the Hendrik Verwoerd Dam spilled for the first time on the 29th February 1972.

III. PHYTOGEOGRAPHICAL ACCOUNT

In phytogeographical writings the eastern grassland region in the Upper Orange River area is generally regarded as being part of the African or Palaeotropic Kingdom. The Kalahari, when it was recognized as a different region, was usually also classified within this floral Kingdom. With regard to the dwarf shrub and succulent-rich flora of the Karoo and Upper Karoo, opinions were divergent as to whether it was palaeotropic in origin or whether it was derived from genuine Cape flora.

In 1872 GRISEBACH published an important work dealing with the vegetation zones of the world as related to climate. Much of the information in this book was drawn from the diaries of early travellers. Largely based on BURCHELL's (1822-24) observations, that the Orange River formed a "botanical limit", GRISEBACH reckoned the Orange River to be the border between the Cape floral Region and the Kalahari floral Region, in which the Highveld and the Transvaal were also included. GRISEBACH's most important reason for considering the Karoo flora to be part of the Cape floral Region, were the narrow ericoid leaves of the Karoo plants and the predomination of synantheroid families (particularly Asteraceae) in the Karoo flora. BOLUS (1875) considered BURCHELL's observation and GRISEBACH's conclusion to be wrong, and held that the only sharp phytogeographical boundary in southern Africa is the one between the true Cape flora and the flora of the interior running along the Swarteberge and the Hex River. The sharpness of this boundary was demonstrated much later by LEVYNS (1950). BOLUS emphasized that the flora of the Karoo differed more from that of the Cape Region than from that of the Kalahari and that there was no sharp boundary between the Karoo and Kalahari floras. A possible boundary could be drawn south of the Orange River, where patches of red Kalahari sand start to occur. BOLUS considered distinguishing the Karoo as a separate third flora province, characterized by its shrubby composites. REHMANN (1881) agreed with the major borderline as proposed by BOLUS, emphasizing the differences between the Karoo flora and the true Cape flora. ENGLER (1882) and MARLOTH (1887, 1908) also did not consider the Orange River to be the southern limit of the Kalahari floral Region. Although ENGLER recognized the Karoo as a flora different to the Kalahari he included it in his class "Steppen des palaeotropischen Florenreiches", as opposed to the flora of the southwestern Cape and the southern coastal strip. He supported these ideas with species lists. In 1886 BOLUS published a map which shows southern Africa subdivided into five natural floral regions. The Upper Orange River valley upstream of Aliwal North falls in the Tropical African Region (= GRISEBACH's "Soudan"); between Aliwal North and Hopetown the river flows through the northern part of the Composite Region, and further downstream through the Kalahari Region. Short floral descriptions of these regions accompany the map.

According to DRUDE (1890), who divided southern Africa into seven plantgeographical regions, the Upper Orange River valley downstream to the vicinity of Hopetown forms the border between the Highveld or Transvaal Grass Steppe Region, and the South African Plateau Region. Further downstream the Upper Orange River area falls into the Kalahari Region. SCHIMPER's (1898) subdivision is based on climatological, ecological and physiognomic rather than on chorologic criteria. The same applies to POLE EVANS' (1922) classification.

In 1905 BOLUS published a rather extensive floristic account on the plantgeographical regions of South Africa in which he stated that the flora of South Africa exists of two chief types, the Southwestern type, occurring in the southwestern Cape, as delineated earlier by him (BOLUS, 1886), and the African type, occurring over the rest of the country. This amounted to the same major division as ENGLER (1882) had proposed. The African type BOLUS divided into five regions. The Upper Orange River between Aliwal North and Hopetown flows through the "Upper (Composite) Region", whereas upstream of Aliwal North and downstream of Hopetown it flows through the Kalahari Region. In this publication BOLUS was the first person to separate the Namib Region from the Kalahari Region.

Many early authors after GRISEBACH (1872), who himself wrote about several centres of creation, emphasized that, although the flora of the Karoo could have developed from either the palaeotropic African flora or from the Cape flora, or represented a mixture developed from the two floras (e.g. SCHÖNLAND, 1907), there is a high degree of endemism and a special adaptation to dry habitats in the Karoo flora. Hence, various authors concluded that the Karoo flora had probably evolved undisturbed since at least the Mid-Tertiary (DRUDE, 1890; BOLUS, 1905; SCHÖNLAND, 1907; BRUNNTHALER, 1911). Later this point was also stressed by MOREAU (1952) and NORDENSTAM (1965).

BEWS (1925) regarded the flora in the central parts of South Africa as being African in origin. According to him the Karoo flora is derived from the flora of the eastern and northern regions bordering it, but it is not very old. On the contrary, it "represents the final result of plant evolution and the last stage of plant migration in South Africa".

ACOCKS (1953) and MONOD (1957) considered the Karoo flora as developed both from the Cape and from the tropical African floras. ACOCKS based his idea on floristic relationships as well as on similarities in plant-form. Particularly the ericoid dwarf shrub growth form, so common in the Karoo flora, he regarded as being derived from the Cape Fynbos. In 1966 (b) ACOCKS wrote that he consideres the Karoo "a thorough mixture" of the Tropical flora, the Cape flora and the Temperate Desert flora (which includes the Strandveld, the Namaqualand Broken Veld and the Succulent Karoo; ACOCKS, 1953), but that the affinity of the Karoo flora lies more with the Cape and Temperate Desert floras than with the Tropical floras. In his extensive account on the chorological regions of Africa, MONOD (1957) considered the establishment of an Austral Empire as against a Palaeotropical Empire. The Austral Empire would comprise a Cape Region and a Karoo-Namaqualand-Namib Region, and this latter Region consists of a Karoo Domain, a Namaqualand Domain and a Namib Domain. Finally he hesitantly kept the Cape Flora autonomous in its own Empire or "Groupe" and placed the Karoo-Namib Region in the "Groupe Tropico-Africain". The Karoo flora was placed in the Karoo Domain (B.IV.1). The eastern grassland and the Kalahari were also placed in the "Groupe Tropico-Africain", but in the "Région Soudano-Angolane", which is synonymous with Sudano-Zambesian Region. This Region comprises the Types "sahariens", "sahéliens" and "soudaniens". The eastern grasslands fall into the Highveld Domain (B.I.(B.b)4.3) of the "Sous Groupe Sud", of the Sahelian Type, whereas the southern Kalahari falls into the Kalahari Domain (B.I.(B.b) 4.1) of the same subgroup. In 1971 MONOD emphasized again that "le Kalahari est pour moi une zone sahélienne sud". The work of MONOD (1957) was an elaboration and to some extent a modification of the chorological classification of Africa by LEBRUN (1947). LEBRUN had already drawn the main phytogeographical boundary that separates the "Région du Cap", comprising the Cape flora proper, from the "Région Sudano-Zambezienne", comprising the remainder of southern Africa. Virtually the entire Upper Orange River area was included in LEBRUN's "Domaine du Namaqualand et du Karroo" of the latter "Région", and only the easternmost part was included in the "Domaine des savannes et fôrets sud-africaines" of the same "Région" (LEBRUN, 1947; cf. MULLENDERS, 1955).

BREMEKAMP (1935), dealing with the flora of the Central Kalahari, stressed the floristic richness of the Karoo and southern Kalahari compared to the Central Kalahari and proposed the latter as a separate subprovince of the East and South African savannas (Sudano-Zambesian Region). MENDONÇA (1961) also regarded the flora of the Kalahari as being distinct enough to enable recognition of a Kalahari Subdomain within the Angolan-Zambesian Domain.

GOOD (1964) divided southern Africa into two major floristic units, a Palaeotropical Kingdom and a South African Kingdom. Within the Palaeotropical Kingdom he distinguished an African Subkingdom which comprises, amongst others, the South African Region. This Region is subdivided into (a) the Highveld of the Orange Free State and Transvaal, (b) the Kalahari, (c) the Karoo, (d) Namaqualand and Damaraland and (e) Natal and the eastern Cape Province. The South African Kingdom consists solely of the Cape Region, confined to the area already delineated by ENGLER (1882), BOLUS (1905) and LEBRUN (1947). Also TAKHTAJAN (1969) distinguished these two kingdoms. Within the Palaeotropical Kingdom he also recognized an African Subkingdom, with amongst others a Sudano-Angolan Region, which is rather similar in extent to MONOD's (1957) region of the same name. The grasslands of the Orange Free State and the eastern Cape Province belong in TAKHTAJAN's classification to the South Tropical African Subregion, whereas the southern Kalahari belongs to the Kalahari Subregion. He also distinguished a Namib-Karoo Region.

In an extensive study based on the distribution of forest trees WHITE (1965) delineated the Sudano-Zambesian Region in more detail. He recognized three domains of which the southern most one, the Zambesian Domain, also comprises the southern Kalahari and the eastern grasslands (also CHAPMAN & WHITE, 1970; WHITE, 1971). Giving strong evidence for his point of view with distribution maps of several species occurring in the southern Kalahari, VOLK (1966a) partly disagreed with WHITE and included the southern Kalahari (as delineated by LEISTNER, 1967, including most of the Vryburg Shrub Bushveld, ACOCKS, 1953) in the Karoo-Namib Region.

Recently, attention has been frequently drawn to biogeographical similarities between the amphitropical arid areas in Africa (MOREAU, 1952; VOLK, 1964, 1966a; DE WINTER, 1966, 1971; WINTERBOTTOM, 1967; VERDCOURT, 1969; MONOD, 1971). Some authors explain this phenomenon on the basis of originally continuously distributed taxa, of which the areas have been secondarily diminished as a result of a subsequent increase in humidity of climate. Rather than being a simple increase in humidity of climate, these changes were cyclic fluctuations in precipitation and temperature during the Quarternary, according to VAN ZINDEREN BAKKER (1964, 1969a) and COETZEE (1967). Thus at various intervals in time an "arid corridor" was created between the southwestern and northwestern dry areas of the African continent, allowing temporary migration of species. AXELROD's (1952) claim, that at least since the Eocene the "successively drier and drier environments gradually expanded" seems at least partially contradictory with the above-mentioned theory of increasing humidity and decreasing distributional areas of semi-arid taxa. AXELROD explained the phenomenon of disjunct semi-arid taxa by long-distance dispersal, arguing that "the highest probabilities of long-distance dispersal for species representing different plant communities ....have generally coincided with the maximum distribution of particular communities".

A strong argument against long-distance dispersal of these semi-arid plants was raised by STOPP (1958), who showed that antitelechoric mechanisms occur frequently in the arid flora of the Karoo-Namib Region, as is the case in other arid and semi-arid areas (cf. MURBECK, 1919, 1920; ZOHARY, 1937, 1962; VAN DER PIJL, 1969). In the grassland flora of the Orange Free State these mechanisms occur only rarely, while they are not present in the flora of the Drakensberg and Natal. This abundance of antitelechory in the arid flora also explains, according to STOPP, the high degree of endemism in the Karoo-Namib Region.

Several other explanations for the disjunct distribution patterns have been proposed, just as for disjunct amphitropical similarities in the arid parts of America (compare WERGER, 1973c).

Most of the taxa with disjunct distributions occur in the Saharo-Sindian Region and the Sahelian zone of the Sudano-Zambesian Region in the northern hemisphere and in the Karoo-Namib Region and the southern Kalahari in the southern hemisphere, which provides strong additional support to VOLK's (1966a) proposal to include the southern Kalahari into the Karoo-Namib Region. Recently WERGER (1973b) applied the method proposed by TOLMATSCHEW (1971) to test the phytogeographical affinities of the southern Kalahari with the Sudano-Zambesian Region and with the Karoo-Namib Region. It was found that the southern Kalahari has considerably stronger affinities with the Karoo-Namib Region than with the Sudano-Zambesian Region, and that the inclusion of Kalahari dune-veld and the Vryburg Shrub Bushveld into the former as proposed by VOLK (1966a) seems justified.

Traditionally it was thought that the Cape flora had a southern origin (e.g. SCHÖNLAND, 1907; HUTCHINSON, 1946; ACOCKS, 1953, 1966b) and had invaded tropical Africa and even Mediterranean Europe along the East African mountain ranges. More recently LEVYNS (1958, 1962, 1964) and BEARD (1959) argued that the Cape flora had a northern origin and had migrated southward along the eastern mountains into the temperate Cape area, where it speciated exuberantly in a floristic vacuum. Rejecting mechanisms like migration ADAMSON (1960), CROIZAT (1962, 1965, 1967, 1968) and WILD (1968) considered the present occurrence of "apparent Cape taxa" in the eastern mountains to represent a remnant of a formally much wider distributed "Cape" flora. Simultaneous speciation in different parts of the formally continuous areas of the taxa and subsequent decrease of the area because of a drying up of the climate, explain the conspicuously large number of vicarious species and endemics in the present area of distribution. A detailed phytogeographical study of the Cape flora was published by WEIMARCK (1941), who distinguished five centres of endemism in Capensis as well as eight floral elements and 17 phytogeographical species groups in its flora.

NORDENSTAM (1969) stressed that the history of each genus must be judged on its own merits and seldomly fits into a standard scheme. But contrary to CROIZAT (1965), NORDENSTAM considered a subdivision of southern Africa into floral regions worthwhile; even if it would only be for practical reasons. Based on his study on *Euryops* NORDENSTAM distinguished nine phytogeographical centres in South Africa, which agree partly with CROIZAT's (1965) delineation of "centres of massing and form-making". These centres should be regarded as foci of differentiation or as evolutionary centres which became established far back in geological history. Therefore, NORDENSTAM (1969) as well as CROIZAT (1965, 1968) do not want to explain present distribution patterns as a result of Pleistocene alterations in climate. NORDENSTAM also warned against a tendency to particularize the Cape Flora.

In 1965 WHITE (also CHAPMAN & WHITE, 1970; WHITE, 1971) proposed the Afro-montane Region, distributed as an archipelago mainly along the eastern African mountain ridges, to be recognized as an independent phytogeographical unit. A large number of taxa show distribution patterns which characterize this region very clearly (CHAPMAN & WHITE, 1970). Taxa typical of this Afro-montane Region occur in the Upper Orange River area on mesic sites in the section east of Aliwal North.

The Afro-alpine Region, originally proposed by HAUMAN (1955) analysed by HEDBERG (1965) and of which the southern part was distinguished as the Austro-afro-alpine zone by COETZEE (1967), does not reach the Orange River within the borders of South Africa. The flora of the uppermost reaches of the Orange River in Lesotho is Afro-alpine, however (compare VAN ZINDEREN BAKKER & WERGER, 1973).

From the above-given literature survey it becomes clear that the entire Upper Orange River area falls within the Palaeotropis. A meaningful chorological subdivision of the Upper Orange River area results in the following pattern:

a) east of Aliwal North on mesic sites: Afro-montane Region;
b) between Aliwal North and the escarpment near Petrusville and east of Aliwal North on less mesic sites: Zambesian Domain of the Sudano-Zambesian Region;
c) west of the escarpment near Petrusville: Karoo Domain of the Karoo-Namib Region.

Detailed data on the distribution of species within the borders of the Republic of South Africa are only possessed by Mr. J.P.H. ACOCKS, in an unpublished form unfortunately. In a recent paper on the distribution of grasses ACOCKS (1971) recognized nine patterns. On a somewhat coarser scale these patterns seem to confirm that in the Upper Orange River area a major division exists separating his pattern 1, from his patterns 3, 4 and 8. This would affirm the subdivision into the Karoo-Namib Region, including the southern Kalahari, and the Sudano-Zambesian Region, to which the eastern grasslands and the False Upper Karoo belong. Patterns 2,6,7 and 9 show the strong connection between the temperate Cape and the Afro-montane floras.

Without attempting a more detailed chorological subdivision of southern Africa in general and of the study area in particular the following lists enumerate some species occurring in the study area, which are in southern Africa typical of the phytogeographical pattern outlined above. Information for these lists is mainly derived from unpublished distribution maps of Mr. J.P.H. ACOCKS (ACOCKS, n.d.) with some additional information taken from WEIMARCK (1941), HEDBERG (1965), CHAPMAN & WHITE (1970) and BAMPS (1971).

Species typical of the Afro-montane Region are *Carex spicato-paniculata, Cliffortia linearifolia, Clutia pulchella, Danthonia disticha, Festuca caprina, F. longipes, Hypericum aethiopicum, Leucosidea sericea, Ochna atropurpurea, Rhus dentata, R. divaricata, Rubus ludwigii* and *Satureia biflora.*

Species occurring mainly in the Afro-montane Region of southern Africa and in the Cape Kingdom are *Blechnum australe, Festuca scabra, Gerbera piloselloides, Halleria lucida, Helichrysum odoratissimum, H. rosum, Helictotrichon longifolium, Heteromorpha arborescens, Kiggelaria africana, Koeleria cristata, Linum thunbergii, Melica decumbens, Metalasia muricata, Mohria caffrorum, Myrsine africana, Pentaschistis setifolia, Rhamnus prinoides, Schoenoxiphium sparteum, Silene capensis* and *Stachys aethiopica.*

Typical Capensis species occurring in the study area are probably only *Antizoma capensis, Asparagus capensis, Ehrharta erecta* and *Erica caffra.*

Species with a Sudano-Zambesian distribution pattern include *Achyranthes aspera, Anthospermum rigidum, Aristida bipartita, Blepharis integrifolia* (mainly southwestern part), *Brachiaria serrata, Celtis africana, Commelina africana, Cussonia paniculata* (mainly on mountainous sites), *Cymbopogon excavatus, C. plurinodis* (also Capensis), *Dicoma anomala, Elyonurus argenteus, Eragrostis capensis* (also Capensis), *E. chloromelas, E. gummiflua, E. plana, E. racemosa, Euclea crispa, Euphorbia clavarioides* (mainly southern part), *E. striata, Haplocarpha scaposa, Harpochloa falx, Helichrysum caespititium, H. nudifolium, H. rugulosum, Hermannia depressa, Heteropogon contortus* (also central parts of South Africa and in Capensis), *Hyparrhenia hirta* (also in Capensis), *Lactuca capensis, Microchloa caffra, Polygala amatymbica, Rhus erosa* (southern part only), *Rhynchosia adenodes, Schistostephium crataegifolium, Setaria flabellata* (also Capensis), *Themeda triandra* (also Capensis and Afro-montane Region), *Trichoneura grandiglumis* and *Walafrida densiflora.*

Species with a typical Karoo-Namib distribution pattern include *Acacia mellifera* subsp. *detinens, A. giraffae, Aizoon schellenbergii, Aloe claviflora* (mainly southern part), *A. hereroensis, Aptosimum albomarginatum, A. leucorrhizum, A. marlothii, A. spinescens, Asthenatherum glaucum, Barleria lichtensteiniana, B. rigida, Boscia albitrunca, Cenchrus ciliaris, Cleome angustifolia* subsp. *diandra, Enneapogon brachystachyus, E. scaber, Eragrostis brizantha, E. denudata, E. echinochloidea, E. porosa, Eriocephalus pubescens, E. spinescens, Euphorbia aequoris* (mainly southern part), *Fagonia minutistipula, Fingerhuthia africana, Hermannia abrotanoides, H. desertorum, H. spinosa, Hoodia gordonii, Limeum aethiopicum, Lycium prunus-spinosa, Microloma massonii, Monechma desertorum, M. divaricatum, M. incanum, Nestlera humilis* (mainly southern part), *Pentzia incana, P. lanata, Phaeoptilum spinosum, Plinthus cryptocarpus, P. karooicus, Psilocaulon absimile, Pteronia glauca* (mainly southern part), *P. sordida, Rhigozum trichotomum, Sarcocaulon patersonii, Senecio longiflorus, Stipagrostis ciliata, S. namaquensis, S. obtusa, Thesium hystrix* (mainly southern and eastern parts) and *Zygophyllum gilfillani.*

Species having their main distribution in the central parts of South Africa restricted to a more or less narrow zone at both sides of the boundary between the Sudano-Zambesian and the Karoo-Namib Regions include *Aloe broomii* (mainly southern part), *Aptosimum depressum, Aristida diffusa* var. *burkei, Asparagus striatus* (mainly southern part), *Aster muricatus, Blepharis villosa* (mainly southern part), *Chrysocoma tenuifolia, Convolvulus boedeckerianus, Cyperus usitatus Dimorphotheca cuneata* (mainly southern part), *Enneapogon scoparius, Eragrostis lehmanniana* (also Karoo-Namib Region),*E. obtusa, Eustachys paspaloides* (also Sudano-Zambesian Region), *Geigeria filifolia* (also Karoo-Namib Region), *Gnidia polycephala, Haworthia tesselata, Helichrysum dregeanum* (towards Sudano-Zambesian Region), *H. lucilioides* (towards Karoo-Namib Region), *H. zeyheri, Hermannia coccocarpa, H. linearifolia, H. pulverata, Hibiscus marlothianus, Indigofera alternans* (also Karoo-Namib Region), *Lessertia pauciflora, Mariscus capensis, Mestoklema tuberosum, Nananthus vittatus, Nenax microphylla* (towards Sudano-Zambesian Region). *Nestlera conferta, Osteospermum leptolobum, O. scariosum, Pachypodium succulentum* (mainly southern part), *Pegolettia retrofracta* (also Karoo-Namib Region), *Pentzia globosa, P. sphaerocephala, Phymaspermum parvifolium, Pterothrix spinescens, Rhigozum obovatum, Rhus ciliata* (mainly northern part), *R. undulata* var. *burchellii* (rather widespread), *Sutera halimifolia, Tragus koelerioides, Trichodiadema pomeridianum* and *Walafrida saxatilis* (towards Sudano-Zambesian Region).

Species with a wide distribution not exemplifying the above-given chorological classification include *Acacia karroo, Aristida congesta, A. curvata, Asclepias fruticosa, Asparagus suaveolens, Boophane disticha, Eragrostis curvula* (not in Karoo-Namib Region), *Olea africana, Pentarrhinum insipidum, Pollichia campestris, Rhus pyroides, Rhynchelytrum repens, Sarcostemma viminale, Talinum caffrum* (not in Capensis), *Tragus berteronianus* and *Ziziphus mucronata* (not in Capensis).

IV. THE STUDY OF VEGETATION AND THE ZÜRICH-MONTPELLIER APPROACH

The origin of the investigation of vegetation as a study of its own is often conveniently associated with the name of Alexander VON HUMBOLDT, although since Conrad VON GESNER (1516-1565) naturalists frequently added ecological notes to their lists and descriptions, and the first real ecological treatise was already published in 1783 by Jean Louis GIRAUD-SOULAVIE (SCHMITHÜSEN, 1957; MÖBIUS, 1968). HUMBOLDT and other nineteenth century botanists, like HEER, SCHOUW, GRISEBACH, VON POST, KERNER VON MARILAUN, HULT and others, developed a concept of vegetation based on physiognomic units, which were often called formations (cf. WHITTAKER, 1962). Many different interpretations were attributed to the term formation, from which with time the one advocated by GRISEBACH (1872) prevailed. The development of the physiognomic tradition in the study of vegetation, well documented by WHITTAKER (1962), resulted in several physiognomic classification systems, of which some commonly used, recent ones include those of C.S.A. (1956) (cf. BOUGHEY, 1957; GRANDVAUX BARBOSA, 1970; GUILLAUMET & KOECHLIN, 1971), DANSEREAU (1958), ELLENBERG & MUELLER-DOMBOIS (1967) (cf. BELLOT & RON, 1970), UNESCO (1966) (cf. KÜCHLER & MONTOYA MAQUIN, 1971) and FOSBERG (1967). Although the formation seems to be the most widely used of all vegetation units (WHITTAKER, 1962), it provides a classification on a rather coarse level of information. It seems particularly suitable if a first preliminary general description of a large, relatively unexplored area is wanted quickly (ELLENBERG, 1954, 1956; BRAUN-BLANQUET, 1959, 1964; POORE, 1962; DAUBENMIRE, 1968a; GOUNOT, 1969). For more detailed information on vegetation, other criteria than physiognomy, preferably floristical criteria, are required.

At about the turn of the century a number of different classificatory approaches with regard to the study of vegetation developed out of a general tendency towards a more theoretical way of thinking about the nature of vegetation. These different classificatory approaches developed into, what are called by WHITTAKER (1962), the Southern Tradition, or Swiss-French or Zürich-Montpellier School; the Northern Tradition, consisting principally of the Uppsala School; the Russian Tradition with its various centers; the British Tradition and the American Tradition. These five traditions together with the physiognomic and a few other approaches of less importance, all started from the so-called community-unit theory, which implies that vegetation consists of community-types, representing well defined natural entities, which are part of the structure of vegetation and which generally contact one another along narrow boundaries (WHITTAKER, 1956, 1962, 1967). The schools of the community-unit theory often use a method of subjective selection of representative samples of phytocoenoses upon which the classification is based. This is in agreement with the principles of the community-unit theory.

The American classificatory tradition started with the work of COWLES, influenced by WARMING, and was largely developed by CLEMENTS. According to CLEMENTS, the formation, as unit of vegetative cover, should necessarily correspond to the habitat, the unit of the earth's surface. The formation is caused by the habitat, but the habitat is recognized by the formation. The formation is a complex organism or quasi-organism which arises, grows, matures and dies, and when fully developed it constitutes the highest expression of vegetation possible under a particular climate, the climax or climatic climax (WEAVER & CLEMENTS, 1929; WHITTAKER, 1962; LANGFORD & BUELL, 1969). From this basis a complex conceptual system was constructed, that was widely applied in America until the forties and also had a strong influence on British ecology (WHITTAKER, 1962). In South African ecology it completely dominated the scene until the second world war and was also applied thereafter (e.g. BEWS, 1918; PHILLIPS, 1931a, 1934, 1935; KILLICK, 1963). In Europe WALTER (1954a), following earlier Russian authors, developed the concepts of zonal, extrazonal and azonal vegetation, of which the concept of zonal vegetation is largely identical to the climax concept.

In the British Tradition, also strongly influenced by WARMING, the name of TANSLEY dominated for a long period. The central concept in TANSLEY's theory was also the formation, defined as the unit of vegetation formed by habitat and expressed by distinctive growth-forms. TANSLEY regarded habitat as the major factor determining the formation but contrary to CLEMENTS did not overemphasize the climatic factor alone. His formation included climax communities other than the climatic climax, and so he formulated the polyclimax theory (TANSLEY, 1939; WHITTAKER, 1962; LANGFORD & BUELL, 1969; SHIMWELL, 1971). Various South African ecologists have applied the ideas developed by TANSLEY, for example ADAMSON (1938), STORY (1952), EDWARDS (1967), and others.

Generalization about the Russian Tradition is difficult, according to WHITTAKER (1962), mainly because of its magnitude and diversity. The Pole PACZOSKI, who also proposed the term phytosociology, was of much importance in the early days of this tradition. Floristic composition or dominant species were used by various Russian and Polish authors to characterize associations, while not the concept of the association as such but rather the way it is related to ecological series should be regarded as the fundamental and most characteristic feature of the Russian Tradition (WHITTAKER, 1962). BAKUZIS (1959) has given a more detailed account of Russian concepts and methodology in particular as used in forest ecosystem research. Until the present day, however, the Russian concepts of vegetation have penetrated very little outside the Russian sphere of culture.

Originating from the work of VON POST, HULT and SERNANDER, the Northern Tradition, chiefly the Uppsala School, first defined the association as a plant community of definite floristic composition and physiognomy. This characterization was based on uniformity of stratal structure. Later the association was defined as a plant community with definite constants and definite physiognomy, constants being those species, that occur in 90 per cent or more of the samples. The association, which was regarded as a fundamental unit of vegetation (DU RIETZ, 1921, 1923), was to be sampled with a certain minimum area. Later on dominance became emphasized more than constancy, and the most prominent leader of the Uppsala School, DU RIETZ, developed a complete hierarchy of vegetation units defined by dominance, which was not in the last instance meant to compete with the hierarchical classification system developed by the Zürich-Montpellier School (DU RIETZ, 1931; cf. WHITTAKER, 1962; cf. SHIMWELL, 1971). Rivalry between the Uppsala and the Zürich-Montpellier Schools became of such importance, that, in WHITTAKER's (1962) words, "the argument between the northern and southern camps was waged with the special intensity of a civil war".

The foundations of the Zürich-Montpellier School of phytosociology were already laid by SCHRÖTER of Zürich and by FLAHAULT of Montpellier, who in 1910 together proposed the definition of the association, that was accepted by the Third International Botanical Congress in Bruxelles: "An association is a plant community of definite floristic composition, presenting a uniform physiognomy, and growing in uniform habitat conditions. The association is the fundamental unit of synecology" (BRAUN-BLANQUET, 1928, 1959, 1964; WHITTAKER, 1962). This definition became the basis for the general acceptance of the criterion of species composition to define the association. The criterion was lead to its logical conclusion with the concept of character species, being species which have narrow ecological amplitudes and show consequently an optimal presence or cover-abundance in a single association. The condition of relative restriction to an association is called fidelity (BRAUN-BLANQUET, 1928). It should be pointed out that associations are not based just on faithful species but on total floristic composition (BRAUN-BLANQUET, 1915, 1928, 1964). Faithful species are, however, of major importance. On this basis a complete hierarchy of syntaxonomical categories was developed, starting from the basic unit, the association, via alliance and order to class, and with subassociation and variant subordinate to the association (BRAUN-BLANQUET, 1928, 1932, 1951, 1959, 1964; BECKING, 1957). Later the concept of differential species was added to the system, and the definition of character species was modified to "a species with a higher fidelity to one particular syntaxon than to other syntaxa" (WESTHOFF & DEN HELD, 1969; cf. TUOMIKOSKI, 1942). Presence, cover-abundance and vitality can all be taken into account to determine the fidelity of a species to a syntaxon. A five-point scale to determine fidelity was worked out by SZAFER & PAWLOWSKI (1927, cf. BRAUN-BLANQUET, 1928, 1964). According to this scale, species that are exclusive to the syntaxon in a particular geographical region, are called exclusive (treu); species that are found mainly in one particular syntaxon and seldom in others, are called selective (fest); species that are found optimally in one syntaxon, although occurring in several others, are called preferential (hold); species that are indifferent to a particular syntaxon, are called vague or indifferent (vag); and species that are uncommon or rare in a particular syntaxon are called strange (fremd). Only exclusive, selective and preferential species are character species (ELLENBERG, 1956; BECKING, 1957; BRAUN-BLANQUET, 1964; KNAPP, 1971; SHIMWELL, 1971). Provisions are made to allow for minor geographical variations within the association (cf. SCHWICKERATH, 1944, 1954; TÜXEN, 1961; BORHIDI, 1963; OBERDORFER, 1968; KNAPP, 1971). Just as in the Uppsala School, the Zürich-Montpellier School uses plots of a certain minimum size to sample the vegetation.

A few minor schools diverted from the theory of BRAUN-BLANQUET, of which one of the most prominent ones is probably the School of SCAMONI and PASSARGE in East Germany. PASSARGE uses the concept of sociological species groups, constituted of species of the same vegetation layer, which show a similar sociological behaviour, owing to similar ecological requirements. The species in one sociological group often possess similar growth-forms. In certain communities they have their maximum or optimum together whereas they are simultaneously absent from other communities (PASSARGE & HOFMANN, 1964, 1968; SCAMONI et al., 1965; PASSARGE, 1968; cf. DOING, 1962, 1969). The theoretical and practical value of this approach has still to be proven (cf. HOHENESTER, 1970).

The principles expressed by BRAUN-BLANQUET and theoretically further developed by many followers, were applied by ever more workers and gradually this approach became known as that of the Zürich-Montpellier School. The conflict with the Uppsala School was finally solved. Some important historical moments in this process of reconciliation were the Sixth International Botanical Congress in Amsterdam in 1935, at which it was decided to use the Uppsala term sociation for vegetation units characterized mainly by dominance in the different strata, and to reserve the term association for vegetation units characterized by character and differential species in the sense of the Zürich-Montpellier School; and the Seventh International Botanical Congress in Stockholm in 1950 at which it was decided to unite sociations and associations into alliances, and alliances into higher units in the sense of the Zürich-Montpellier School (WHITTAKER, 1962; BRAUN-BLANQUET, 1964).

The gradually increasing success and acceptance of the Zürich-Montpellier approach with regard to the classification of vegetation, first in nearly all countries of Europe and now also in several regions of nearly all continents have been documented by WHITTAKER (1962), BRAUN-BLANQUET (1968) and TÜXEN (1969, 1970a).

Another point of view in regard to the nature of vegetation, and originally completely in contradistinction to the classificatory approaches based on the community-unit theory, was independently developed by GLEASON (1917, 1926) in the U.S.A. and RAMENSKY (1924) in the Soviet Union. This point of view is known as the individualistic concept (cf. WHITTAKER, 1956, 1962, 1967, 1970; CURTIS, 1959; PONYATOVSKAYA, 1961; MCINTOSH, 1967). The individualistic concept is based on two principles. (1) The principle of species individuality postulates that each species is distributed in relation to the total range of environmental factors it encounters according to its own genetic structure, physiological characteristics and population dynamics. No two species are alike in these characteristics, hence probably no two species have the same distribution. (2) The principle of community continuity postulates that communities occurring along continuous environmental gradients usually intergrade continuously, with gradual changes in population levels of species along the gradients (WHITTAKER, 1967).

Thus, not classification of vegetation was aimed at, but "the linking of all biocoenoses studied into an unified coordinate-scheme" (WHITTAKER, 1962). Whereas RAMENSKY's ideas were gradually developed by him and other workers in the Soviet Union (cf.PONYATOVSKAYA, 1961), GLEASON's points of view met with tremendous resistance in the U.S.A. and Europe (cf. WHITTAKER, 1962; MCINTOSH, 1967), although from time to time hypotheses similar but not always going as far as those stated by GLEASON were expressed in Europe (e.g. MATUSZKIEWICZ, 1948; WALTER & WALTER, 1953). With the publications of CAIN (1947), MASON (1947), EGLER (1947) and others, in favour of GLEASON's theory, and even more with the early development of multivariate techniques for testing these hypotheses, particularly in the Wisconsin School (BRAY & CURTIS, 1957; CURTIS, 1959), a renewed interest in the individualistic approach developed (cf. PONYATOVSKAYA, 1961; MCINTOSH, 1967; YARRANTON, 1968; LANGFORD & BUELL, 1969).

At about the same time a third trend developed, mainly in the English speaking part of the world and sometimes called the Southampton School, which took a position somewhat between the points of view of those supporting the community-unit theory and those supporting the individualistic theory. This third trend started from the reasoning, that if there is heterogeneity in the vegetation of a certain region, statistical analysis will detect and estimate this heterogeneity and allow a classification that is in optimal agreement with the existing heterogeneous pattern. Methods developed for this purpose are commonly summarized under the term cluster analysis (GOODALL, 1970; PRITCHARD & ANDERSON, 1971; WILLIAMS, 1971). A large variety of cluster analyses developed, such that a preliminary scheme for classifying this classification methods, constructed by WILLIAMS (1971), proved useful. The most popular method of cluster analysis so far has proved to be WILLIAMS & LAMBERT's (1959, 1960) association analysis (PRITCHARD & ANDERSON, 1971), although this technique was explicitly recommended to be followed up with an inverse and a nodal analysis in order to obtain a more comprehensive classification of vegetation (WILLIAMS & LAMBERT, 1961; LAMBERT & WILLIAMS, 1962). Association analysis, as presented by WILLIAMS & LAMBERT is a much improved version of a procedure described by GOODALL (1953). In association analysis the total of plot samples is subdivided on the basis of negative or positive association between species, calculated on the basis of presence/absence data. The species with the highest sum of the values for the parameter of association is taken as the dividing species for each group of plot samples. As mentioned above, various other cluster techniques were developed and tested, using quantitative or qualitative data or both, based on a variety of sampling procedures, and either agglomerative or divisive (cf. GOUNOT, 1961, 1969; GREIG-SMITH, 1964; KERSHAW, 1964; LAMBERT & DALE, 1964; PIELOU, 1969; GOODALL, 1970; PRITCHARD & ANDERSON, 1971; WILLIAMS, 1971). Divisive techniques are regarded as theoretically better than agglomerative ones (LAMBERT & DALE, 1964; PIELOU, 1969; WILLIAMS, 1971). This is based on the central concept behind these cluster analyses, that heterogeneity in the vegetation should first be detected and estimated statistically, and that classification should be based on this estimate of heterogeneity. Divisive methods, it is reasoned, start from maximal information, whereas agglomerative methods start from minimal information, hence, divisive methods are preferable (cf. LAMBERT & WILLIAMS, 1966). If the central concept of vegetation is that of the community-unit theory, however, agglomerative methods are theoretically preferable, since a sample of sufficient size, representing an association-individual (BRAUN-BLANQUET, 1964) constitutes a real basic vegetation-unit-individual that is, an organized system, radically differing from a merely individually independent assemblage of species (SCHMITHÜSEN, 1957; MAJOR, 1958; TÜXEN, 1970b, WESTHOFF, 1970). From these vegetation-unit-individuals or phytocoenoses, each with its own system of interrelations between its constituent members, conditioning the structure of the phytocoenosis (WESTHOFF, 1970), the type or association is abstracted (VON GLAHN, 1968). It is thus crucial that in the resulting classification the similarities and differences between the basic vegetation-unit-individuals remain maintained and that they form the governing principle of the classification, and not the total heterogeneity in a large abstract sample of vegetation-unit-individuals, as is the case in classifications based on divisive clustering techniques.

Simultaneously with the development of cluster analyses, multivariate techniques for testing of the individualistic hypotheses were also developed. These techniques are often summarized under the term gradient analysis (WHITTAKER, 1967 , 1970; MCINTOSH, 1967) and comprise various ordination and iteration techniques, which are described by ORLOCI (1966), AUSTIN & ORLOCI (1966), GOFF & COTTAM (1967), SWAN et al. (1969), VAN DER

MAAREL (1969), ANDERSON (1971), and others.

Initially the development of cluster and gradient analyses complicated the picture of controversy between the various camps in vegetation science. There was controversy between the "continuists" on the one hand and the "subjective classificationists" and "statistical classificationists" on the other hand about the question of whether to classify or not and there was controversy between the "subjective classificationists" and the "statistical classificationists" about the questions of subjectivity, the necessity of statistical analysis and the utility of artificial statistical classifications (cf. PONYATOVSKAYA, 1961; MCINTOSH, 1967). Mutual misunderstanding, misinterpretation of concepts and incorrect terminology played and important role in this controversy and publications by HULL (1964, 1965, 1968, 1970), JOHNSON (1968), JARDINE (1969), and others, although mainly concerned with a parallel controversy in taxonomy, proved important in clearing up the confusions. Illustrative in this connection are the arguments by POORE (1955, 1956) on the Zürich-Montpellier approach (compare also BARKMAN, 1958; MOORE, 1962). Also dogmatism played an important role (ANDERSON, 1965). Some "statistical classificationists" held that any non-statistically based classification would be wrong by definition (e.g. WEBB, 1954). On the other hand "subjective classificationists" sometimes completely ignored the arguments of the "statistical classificationists" (e.g. BRAUN-BLANQUET, 1964). It is also conspicuous, that the argumentation of supporters of the individualistic theory is for a great part negative, in the sense, that it is pointed out repeatedly that the results of the "classificationists" might perhaps prove their basis correct, but it does at least not prove the individualistic hypotheses incorrect (cf. MCINTOSH,1967). Many workers showed, however, a less dogmatic and more positive approach, indicating that the various procedures might be applied simultaneously and with equal or enhanced success to the same problem and that different points of view should be discussed and integrated to the benefit of ecological theory (GOODALL, 1952, 1971; PONYATOVSKAYA, 1961; GOUNOT, 1961, 1969; LAMBERT & DALE, 1964; ANDERSON, 1965; VAN DER MAAREL, 1969 ; WHITTAKER, 1967, 1970; WILLIAMS, 1967, 1971; LANGFORD & BUELL, 1969; WESTHOFF & DEN HELD, 1969; DOING, 1970; SHIMWELL, 1971; WERGER, 1973d; and others). Thus the once much stressed controversy between the different approaches was eventually played down. A number of studies, applying different techniques to the same set of data proved significant (e.g. GITTINS, 1965; VAN GROENEWOUD, 1965; IVIMEY-COOK & PROCTOR, 1966; GREIG-SMITH et al., 1967; WOODS & MOLL, 1967; KERSHAW, 1968; VAN DER MAAREL, 1969; TAYLOR, 1969; MOORE et al., 1970; PRITCHARD & ANDERSON, 1971; SINGH & WEST, 1971; COETZEE, 1972; WERGER, 1973d; COETZEE & WERGER, 1973). Apart from being academic exercises most of these studies agreed on two points. (1) Application of different methods initially linked to certain concepts about the nature of vegetation proved to give similar and directly comparable, or compatible results. (2) It was often shown that the so-called subjective classificatory techniques proved to be most efficient in terms of either effort expended, or results obtained or both. In this connection it should be noted that often tacitly the possibility of interpretation of the results, which means at least partly subjective observation, is taken as the basis for judgement of suitability or success of the various methods of clustering or gradient analysis. An exception in this respect is formed by the study of PRITCHARD & ANDERSON (1971) who explicitly state that the subjective assessment of situations is adopted as standard for determining "usefulness" of the analyses applied by them. HULL (1970), referring to an earlier work by KAPLAN (1964), pointed out, that these subjective assessments should not be regarded as "lucky guesswork, but as currently unreconstructed logic-in-use". It should also be noted that the way in which associations and other syntaxa are extracted from phytosociological tables in the Zürich-Montpellier School cannot be regarded as a superfluous appendix to the method, mainly functioning to obscure a procedure of fully subjective assessment of "types" in the field. Associations and other syntaxa are extracted in a process of fruitful interaction between the complex whole of conscientious observations in the field and abstracted patterns in the table (cf. VON GLAHN, 1968; compare also POORE's (1962) discussion on the method of successive approximation, and BAMBERG & MAJOR, 1968). Owing to the complexity of vegetation interrelationships in the field, solely subjective assessment of the "types" would at least be unreliable, if not impossible. In this sense, the statements by MCINTOSH (1967), that "the sociological eye allegedly allows the detection of minute floristic differences evidenced by certain species combinations", and "that the followers of BRAUN-BLANQUET's method select a single sample to represent the entire community", are entirely invalid.

Apart from providing unbiased support for the scientific soundness of the subjective classificatory approaches, particularly that of the Zürich-Montpellier School, the results of the statistical analysis procedures urged the need for precise definition of the procedures used by the Zürich-Montpellier School, in other words the reconstruction of the logic of these procedures. As a result of this, recent developments enabled the construction of meaningful phytosociological tables, as used in the Zürich-Montpellier School, by computer, thus proving that this part of the Zürich-Montpellier approach can be totally objective (SCHMID & KUHN, 1970; SPATZ & SIEGMUND, 1970; STOCKINGER & HOLZNER, 1970; CESKA & ROEMER, 1971; GARCIA-MOYA, 1972; PYOTT, 1972). SPATZ & SIEGMUND (1970) also reconstructed by computer a hand made table from ELLENBERG (1956), again proving that table to be scientifically sound. Also the objections against the procedure of subjective sampling are now often regarded as being inappropriate or their strengh being overestimated (e.g. WHITTAKER, 1962; IVIMEY-COOK & PROCTOR, 1966; DAUBENMIRE, 1968a; MOORE et al., 1970). Moreover, this point need not be crucial any longer, since useful phytosociological tables have been compiled from systematically sampled data (TAYLOR, 1969).

Irrespective of purely theoretical considerations many workers agree that classification of vegetation is a necessity for the advancement of the study of vegetation (e.g. WHITTAKER, 1956; DAHL, 1957; GILMOUR & WALTERS, 1964; GRUNOW, 1965; DAUBENMIRE, 1966, 1968a; GOUNOT, 1969; EDWARDS, 1972). The classification attempted should, of course, be adapted to the information wanted and thus to the scale of the survey. As pointed out by EDWARDS (1972), reconnaissance and semi-detailed surveys, mapping at scales between 1 : 500 000 and 1 : 100 000, and between 1 : 100 000 and 1 : 10 000 respectively, are of major importance in defining, classifying and studying community and habitat relations, and in providing the main classificatory reference framework of plant communities, from which prediction and extrapolation for sequential study and for planning can be made. For these scales of surveys of relatively large areas, that are required to yield "a maximum of understanding of the complexity of vegetation and of its relation to en-

environmental factors for a minimum of time input", MOORE et al. (1970) evaluated the Zürich-Montpellier approach as the most suited.

Also worth considering in this context is the versatility of various classification systems. The open-ended hierarchical system of the Zürich-Montpellier School, based on total floristic composition, with an emphasis on character and differential species, allows for the incorporation of new relevés without reserve. When more data become available, Zürich-Montpellier classifications sometimes need revision. This is done with the aid of summarized tables and on the basis of existing classifications.

In connection with the assignment of additional stands to their correct position in a previously established, statistically based classification, GREIG-SMITH (1964) remarks, that "it is always possible to reclassify the whole augmented set of stands [by renewed computation of the entire set of data], but it may be more practical to accept the definitions of groups previously derived and place additional stands accordingly". GRUNOW (1965) remarks that doubling or quadrupling the sample intensity after an initial survey at a lower intensity may, with association analysis, lead to a classification with different communities. Also the size of the sampling unit affects the resulting classification by association analysis, at least at its lower divisions (NOY-MEIR et al., 1970).

It seems to satisfy statistical ecologists that their classifications apply only to the area sampled (cf. LAMBERT & DALE, 1964). Little data are available on attempts to apply statistically based classifications outside the immediate study area, but apparently it involves serious difficulties (cf. NOY-MEIR et al., 1970). The Zürich-Montpellier system aims specifically to be versatile. The School wants to construct an abstract taxonomy of vegetation units of general applicability, from which ecological inferences may be drawn (IVIMEY-COOK & PROCTOR, 1966). The use of total floristic composition with an emphasis on diagnostic species at all levels of the hierarchy, makes the Zürich-Montpellier system suitable for comparison of classifications of geographically separated but chorologically related areas (cf. TÜXEN, 1970b), whereas cluster analysis techniques can only yield ad hoc classifications. Thus, the Zürich-Montpellier system, because of the above-mentioned way in which floristic criteria are used, has achieved "a coherence and consistency denied other systems" (WHITTAKER, 1962).

Hence, the Zürich-Montpellier approach meets three essential requirements: (1) it is scientifically sound; (2) it fulfills the necessity of classification at an appropriate level; (3) it is the most efficient and versatile amongst comparable approaches. These qualities, which make this approach one of the most significant tools in the study of the environment (cf. for example KNAPP, 1965; HAASE, 1968; SCHMITHÜSEN, 1968b; TROLL, 1968; TÜXEN, 1968-69, 1970b), are of decisive importance in the justification for its use in the present and other studies.

V. ON CONCEPTS AND METHODS APPLIED IN THE PRESENT STUDY

Of the early ecological studies in South Africa the comprehensive treatise on the vegetation of the Cape Province by MARLOTH (1908) is perhaps the most prominent one. For more than half a century thereafter South African ecology was predominantly inspired by the writings of CLEMENTS (e.g. BEWS, 1918; PHILLIPS, 1931b; BAYER, 1955; KILLICK, 1963) and TANSLEY (e.g. ADAMSON, 1938; STORY, 1952; EDWARDS, 1967). The studies of this period, discussed in somewhat more detail by KILLICK (1966-67), were mainly of a non-formal descriptive nature and often admirably accurate and informative. During the early fifties two techniques were developed, which had a major impact on subsequent local ecological studies. In 1953 ACOCKS published his "Veld Types of South Africa", a classification of South African vegetation into 70 veld types and 75 variations, based on a floristic comparison of stand data. ACOCKS selected well-developed, extensive patches of vegetation and recorded all species encountered. Abundance of each species in each stand was estimated and from comparison of these lists the veld types were extracted. Since its publication ACOCKS' Veld Types has formed the basis of the majority of ecological studies carried out in South Africa. In 1955 TIDMARSH & HAVENGA published an account of a wheel-point method of survey and measurement of cover of vegetation, which has since been used extensively in southern Africa in its original form and in modified ways.

The development of statistical techniques in ecology received attention in South Africa soon after their introduction in Europe and America, and mainly from 1960 onwards several studies were undertaken using GOODALL's (1953) interspecific correlation analysis (VAN VUUREN, 1961), association analysis (e.g. GRUNOW, 1965; ROBERTS, 1966; SCHEEPERS, 1969; TAYLOR, 1969; COETZEE, 1972), information analysis (GRUNOW & LANCE, 1969), hierarchical syndrome analysis (COETZEE & WERGER, 1973) and various kinds of ordination techniques (e.g. WOODS & MOLL, 1967; MORRIS, 1969; MOLL, 1969; GRUNOW & MORRIS, 1969; LOUW, 1970).

The methods applied by the Zürich-Montpellier School were not used in South Africa before 1969. As a main reason for this remarkable omission WERGER et al. (1972) suggested, amongst others, language difficulties. Although English accounts on the method were given by BRAUN-BLANQUET (1932), POORE (1955, 1956), BECKING (1957) and MOORE (1962), the local psychological climate was by then so influenced by the attitude of general non-acceptance of the method, which prevailed amongst the English-speaking ecologists, that its application was not attempted. Thus, the present study was the first one initiated in South African ecology, that was carried out entirely according to the method of the Zürich-Montpellier School. In the meantime, however, a number of smaller studies applying this method, have been published or completed (VAN ZINDEREN BAKKER, 1971; WERGER et al., 1972; LEISTNER & WERGER, 1973; WERGER, 1973a; VAN ZINDEREN BAKKER & WERGER, 1973). The success of these studies has been extremely encouraging, and a wider acceptance of the Zürich-Montpellier method in South Africa is envisaged.

According to the Zürich-Montpellier method selected, representative, homogeneous plots of a certain minimum size, are sampled in the vegetation of the area to be surveyed, recording all species and rating them on a cover-abundance scale. Some other analytical characters of the vegetation in the quadrat might also be recorded. The samples are entered in a table from which the vegetation units are extracted. The units are interpreted ecologically and ranked in a hierarchy. The various concepts and techniques involved in this procedure will be discussed in somewhat more detail in the following section, without any pretention at being complete.

V.1 SAMPLING

V.1.1 Site selection

In the Zürich-Montpellier School the selection of sites for a plot is generally carried out subjectively. Although much and severely critized, this procedure is in accordance with the community-unit theory, which postulates that vegetation consists of natural entities, generally contacting each other along narrow boundaries (see Chapter IV and WHITTAKER, 1962). In order to find the units or associations, which are types abstracted from actually occurring stands or phytocoenoses, it is most efficient to select those stands for sampling which might possibly be an example of such an association. Stands which are obviously heterogeneous in habitat, structure or floristic composition, such that they might comprise parts of two or more units or associations should be avoided because they do not contribute information which can be used to describe any of the community-types they comprise. Thus, the subjective decision to avoid mixed stands does not imply that the circularity suggested by WHITTAKER (1956) does exist: "associations are being studied in terms of samples taken in terms of associations". The real procedure is, that associations are being studied in terms of plot samples taken in terms of phytocoenoses which are possible association-individuals. It is obvious, that the question of subjective selection of phytocoenoses for sampling is closely related to the questions of representativeness, homogeneity and total number of plots to be sampled. It is important that the area of investigation is well-known in all its variety before the study is started, since a good knowledge of the variation in the study area allows a more representative sampling of the various phytocoenoses. Prejudice about the expected results of the study should be avoided in this selection. The subjective selection of stands for sampling guarantees an optimal sampling efficiency, because obviously heterogeneous plots are avoided as far as possible (ELLENBERG, 1956; BECKING, 1957; DAHL, 1957; BARKMAN, 1958; GOUNOT, 1961, 1969; BRAUN-BLANQUET, 1964; DAUBENMIRE, 1968a; KNAPP, 1971). The strength of the arguments against the procedure of subjective selection of plot sites is often overestimated, since it seems to be difficult, according to the experience of IVIMEY-COOK & PROCTOR (1966) to "collect any substantial body of phytosociological data to support a conclusion seriously at variance with the facts". On the other hand this question need not be crucial in the decision to apply the Zürich-Montpellier methods, since there is no fundamental objection against stratified random, random and systematic sampling. These sampling strategies can yield good results too. However, particularly in the last two cases, a considerable number of plot data will be too heterogeneous to be used in the extraction of community-types (cf. TAYLOR, 1969). A test for homogeneity of the plots might prove useful, when these strategies are used. When they are used in an area where different communities occur in a mosaic of patches of small dimensions, the possibility exists that virtually no plot may be usable or, that so many plots are situated on similar transitions that these transitions are also extracted from the tables and wrongly be interpreted as types. Great care should thus be taken in evaluating the plot data and the synthetic results based on random and systematic sampling strategies.

In the present study the stands for sampling have been selected subjectively on the basis of representativeness and homogeneity, two concepts to be discussed below.

V.1.2 Representativeness

Stands for sampling should be selected such that each stand is representative of the vegetation of which it is part and that each plot sampled therein should yield a more ore less typical description of that vegetation in terms of both floristic composition and structure. Each plot should only represent one entity of vegetation (ELLENBERG, 1956; DAHL, 1957; GOUNOT, 1961; BRAUN-BLANQUET, 1964; KNAPP, 1971). In an open tree or shrub vegetation, for example, plots should be situated such that the relative importance of the tree or shrub component within the plot is comparable to that of the surrounding vegetation represented in the plot.

The requirement of representativeness of the vegetation in the sample plot shouid not be confused with the question of optimal development of the vegetation. Although samples taken in optimal developed vegetation are most suitable for first description of new syntaxa (WESTHOFF, 1967, 1968; WESTHOFF & DEN HELD, 1969), it will often be very useful to sample stands representative of less optimal developed vegetation, such as overgrazed grasslands. Such a sample is important in establishing the status of the grassland concerned and the successional trends under the influence of a specific treatment of the vegetation to which the sample belongs. When random or systematic sampling is carried out the question of representativeness of each individual plot is of course bypassed. This is an important disadvantage in open vegetation in particular.

The question of representativeness of a plot is closely related to the question of homogeneity of the plot.

V.1.3 Homogeneity

According to GOODALL (1952), "homogeneity has bulked large in ecological literature, because most schools of plant sociology specify it as a first desideratum for a 'stand', or area of vegetation, which can serve as a unit of classification".

Both the approaches based on the community-unit theory and those based on the individualistic hypotheses require homogeneous sample plots (BRAY & CURTIS, 1957; CURTIS, 1959; GRUNOW & MORRIS, 1969). Workers using the various ordination techniques often assess only floristic homogeneity of the sample plot, relating homogeneity to the distribution of the species present in the sample plot. In the Zürich-Montpellier School floristic,structural and environmental homogeneity is usually assessed visually. Homogeneity is so important in the community-unit theory approaches, because information per sample of one vegetational entity only and not of mixtures is wanted (ELLENBERG, 1956; DAHL, 1957; BARKMAN, 1958; GOUNOT, 1961, 1969; BRAUN-BLANQUET, 1964; DAUBENMIRE, 1968a; TÜXEN, 1970b; KNAPP, 1971; SHIMWELL, 1971). Most techniques for testing homogeneity of the sample plot start tacitly from the assumption, that if either the plot is floristically homogeneous, it is also structurally and environmentally homogeneous, and thus, only floristic homogeneity need to be tested, or that structural and environmental heterogeneity not expressed in the floristic component is irrelevant.

Homogeneity was first discussed by NORDHAGEN (1923) and soon became the object of a polemic between KYLIN and ROMELL(cf. KYLIN, 1923, 1926; ROMELL, 1925, 1926). KYLIN, assuming that, on the average, the species in a community are distributed randomly, regarded homogeneity as depending on variations in density among the species and suggested that species-area curves and frequency-distribution curves are useful tools in determining the homogeneity of a patch of vegetation. KYLIN (1926) distinguishes between homogeneity of vegetation based on the distances between the individuals of a species, which is homogeneity in the sense of NORDHAGEN (1923), and homogeneity of vegetation based on distances between all the various species, which deals with the composition of the vegetation. ROMELL (1925, 1926), who also distinguishes homogeneity of distribution from homogeneity of composition, points out with respect to the former that homogeneity is a matter of scale. Although a patch of vegetation might be heterogeneous if studied on a small scale, as a consequence of the fact that plant-individuals occur as discrete units, the same area might be homogeneous when studied at a larger scale. This matter of scale also applies for plants occurring in clumps (compare also GOODALL, 1954a, 1961, 1970; VAN DER MAAREL, 1966a). Since more often plant individuals are under- or overdispersed (cf. ASHBY, 1948; GOODALL, 1952, 1970; AUGARDE, 1957; GREIG-SMITH, 1964; KERSHAW, 1964) than randomly distributed, the question of scale is of crucial importance in statistical tests for homogeneity. Thus, TUOMIKOSKI's (1942) proposal to determine homogeneity on lack of correlation between the occurrence of different species, is also meaningless if the question of scale is not regarded at the same time.

DAHL & HADAC (1949) gave a definition of homogeneity that is often regarded as fairly satisfactory: "A plant species is said to be homogeneously distributed within a certain area if the probability to catch an individual of a plant species within a test area of given size is the same in all parts of the area. A plant community is said to be homogeneous if the individuals of the plant species which we use for the characterization of the community are homogeneously distributed". They continue to point out that plant communities are never fully homogeneous and that one should be satisfied with more or less homogeneous plant communities. They also state, that "the human eye, badly adapted to measurement, but well to comparison, rapidly gives the trained sociologist an impression whether a plant community he has before his eyes is highly homogeneous or not". As pointed out by GOODALL (1961), the definition by DAHL & HADAC (1949) does not fit vegetation with a mosaic pattern. GOODALL (1961) then suggested the following definition:

"the distribution of a species in an area of vegetation is homogeneous if there exists some sample size for which the variation between replicate samples is independent of the distance between them". Hence, the question of homogeneity is linked to the concept of minimum area. If homogeneity in the sense of GOODALL (1961) could be proved, then a statistically valid minimum area would exist (cf. GOODALL, 1961; KERSHAW, 1964). Testing GOODALL's definition involves, however, a considerable amount of cumbersome field work' and computation. Besides, this and other tests usually do no more than give an indication of the degree of heterogeneity.

Since many ecologists agree with GREIG-SMITH (1964), that "empirical description of vegetation cannot wait for clarification of theoretical concepts", in particular not if these concepts bear relatively little importance in many fields of ecological interest, the suggestion of subjective assessment of homogeneity by DAHL & HADAC (1949) has often been restated (e.g. ELLENBERG, 1956; DAHL, 1957; BRAUN-BLANQUET, 1964; DAUBENMIRE, 1968a; KNAPP, 1971). For instance DAUBENMIRE (1968a) defines a homogeneous patch of vegetation as "one in which variations are attributable to chance, rather than to intrinsic habitat factors", and comments that one should not try to find homogeneity but rather try to eliminate as much heterogeneity as possible. This should be done subjectively, because "the results of lengthy computation often do no more than verify vegetation discontinuities that are evident to a trained synecologist by careful inspection". An ecological definition of homogeneity, which is virtually impossible to test statistically, is given by GODRON (1968): "une station est homogène lorsque chaque espèce peut y trouver des conditions de vie équivalentes d'une extrémitée à l'autre, et non pas en tous les points de la station".

In the present study, the practical approach is taken in assessing homogeneity of the sample plot subjectively in terms of as little as possible obvious heterogeneity in floristics, structure and environmental features, and in ascribing a good deal of reliability to experience.

V.1.4 Minimal area and plot size; plot form

Another much discussed and critisized concept is that of minimal area, most recently by WERGER (1972). Two basic approaches to the concept of minimal area can be observed.

(1) The approaches based on the community-unit theory try to determine a certain minimal size of area in which the community can represent itself. The determination of this size of area is important, since communities can most efficiently be sampled with plots of the size of minimal area or slightly over. If a community is sampled with plots smaller than the minimal area then the community-type cannot easily be extracted from the data; if it is sampled with plots larger than the minimal area then much effort is waisted.

(2) One aim of the statistical approach to vegetation is to establish whether plant communities exist or not. This involves pattern studies and thus leads automatically to studies of minimal area, again as the minimum size of area in which the possibly existing community can represent itself.

In the community-unit theory approaches, however, two concepts under the label of minimal area are often confused: the analytic and the synthetic concepts of minimal area. The analytic concept of minimal area implies the determination of the size of area on which a phytocoenosis (community, in WHITTAKER's (1956, 1962) terminology) can fully represent itself, in order to ascertain a suitable plot size for sampling that and similar phytocoenoses. The synthetic concept of minimal area implies the determination of the average size of area on which a particular association (community-type, in WHITTAKER's (1956, 1962) terminology) can represent itself. In order to determine this area it is, amongst other requirements, necessary to know the total number of species of an association (compare RAABE's remarks following a paper by VAN DER MAAREL, 1970).

Since the present study deals with formerly undescribed syntaxa and a suitable plot size for sampling the vegetation was sought, the analytic concept of minimal area will be considered here.

BRAUN-BLANQUET (1913) originally determined minimal area as the area above which no new species occur in the association (probably meaning the phytocoenosis). This size of area is determined with the species-area curve (cf. WERGER, 1972). Later BRAUN-BLANQUET (1928, 1951, 1964) modified this to the area at which the species-area curve becomes more or less horizontal (cf. ELLENBERG, 1956). Recently TÜXEN (1970) reinterpreted this curve, regarding it as consisting of three phases: (a) a strongly curved phase; (b) a slanting straight line; (c) a horizontal line. It seems that this reinterpretation deserves further investigation in order to establish to what degree the three phases are a result of scale and a neglect of mathematical interpolation.

Relative scales of abscissa and ordinate axes are important in determining the position of the inflection point of the species area curve (CAIN & CASTRO, 1959; cf. WERGER, 1972).

The Uppsala School defined minimal area as the area above which there was no increase in constant species, constant being those species which have a percentage frequency over 90% on an area of sufficient size, that is above the minimal area. The constancy-area curve is supposed to show a step, above which only extremely large areas would add new constant species (DU RIETZ et al., 1920; DU RIETZ, 1921).

POORE (1964, 1968) constructed species-area curves for stands of a tropical rain forest in Malaysia and found that only the curves for constant tree species flattened out. HOPKINS (1955, 1957) could, however, neither find a break in the species-area curves nor a step in the constancy-area curves of data of several British stands of vegetation. GOODALL (1970) argued that the asymptotic form of the species-area curve is an illusion due to the use of a linear scale for a measure of area.

Based on a detailed study of Dutch dune vegetation VAN DER MAAREL (1966a) concluded that minimal area cannot satisfactorily be defined as an absolute intrinsic character of the vegetation and advocates a pragmatic approach, defining minimal area as the minimal size of area to be analysed to get a representative view of a phytocoenosis.

Several other definitions of minimal area were attempted (compare GOODALL, 1952; WERGER, 1972) without solving the matter.

CALLéJA (1962), SEGAL (1969), VAN DER MAAREL (1970), WERGER (1972) and others emphasized that apart from floristic richness minimal area also depends on structure of the phytocoenosis. Thus, the species-area relation is an interwoven expression of floristic richness and structure of a patch of vegetation.

Statistical tests, usually based on homogeneity assumptions in a phytocoenosis, failed to determine a minimal area objectively (cf. GOODALL, 1954b, 1961; GREIG-SMITH et al., 1963; GREIG-SMITH, 1964; KERSHAW, 1964), with the possible exception of some vegetation types in Western Australia (GOODALL, 1963).

WERGER (1972), concluded that no convincing minimal-area definition has yet been formulated and regarded the concept unsuitable for ascertaining a suitable plot size for sampling the vegetation.

In the present study plot size was determined according to the optimal plot size procedure described by WERGER (1972). The regression equation of GLEASON (1925), reformulated by GOODALL (1952), and FISHER's equation (FISHER et al., 1943) apparently fit observed species-area relations best (GOODALL, 1952; HOPKINS, 1955; DAHL, 1957; and others). GLEASON's equation was used here to calculate the curves fitting to data from concentric circular plots with a range in area from 0,8 m^2 to 1 520 m^2, taken in a number of homogeneous stands of vegetation representing various vegetation types in the Upper Orange River area (WERGER, 1972). Based on observations by WILLIAMS (1943), that the average uniform population or phytocoenosis seems to manifest itself fully within an area of about a half to one hectare, the number of species to be expected in one hectare of each stand of vegetation sampled was considered s the 100% level of information on each phytocoenosis. It was then calculated how various area sizes to be sampled correspond to various levels of information. These sizes appeared to be dependent on floristic richness and structure of the various phytocoenoses.

It was arbitrarily decided which increase of effort expended in sampling, in terms of increase in plot size, was still worth the corresponding increase in information and which not. Optimum plot size was thus determined at a level of about 50% to 55% of information for each type of vegetation sampled. This meant that for the riverine forest and woodland along the entire Upper Orange River, described in Chapter VI.1, a plot size of 25 m^2 was used; for the grasslands in the eastern part of the Orange Free State and the Eastern Cape, described in Chapter VI.2, 25 m^2; for the shrubby communities on the hillsides in the same area and in the False Upper Karoo, described in Chapter VI.4, 100 m^2; for the dwarf shrub communities of the False Upper Karoo, described in Chapter VI.3, 50 m^2; for the grassland communities on Kalahari sand in the area downstream of Petrusville, described in Chapter VI.6, 50 m^2; and for the dwarf shrub and shrub communities of the False Arid Karoo and the False Orange River Broken Veld, described in Chapter VI.5, 100 m^2 (WERGER, 1972). Only in rare cases in the woody riverine vegetation were plots of 50 m^2 taken.

In the Zürich-Montpellier method one is neither bound to a fixed plot size nor to a fixed plot form in sampling the vegetation of a region, because species are rated on a cover-abundance scale with relative values. However, because of the above-mentioned determination of suitable plot sizes, all the various vegetation types were sampled with the above-mentioned plot sizes.

GOODALL (1952) states that sampling variance is usually less between elongated plots, such as narrow rectangles, than between squares or circles of the same area. As mentioned above, in the present study optimal plot size was determined on data based on circular concentric plots. It was decided, however, to use square plots, because they possess the same characteristics as circular ones, but are easier to lay out.

V.1.5 Structure

In sampling, an important decision with regard to the structure of a phytocoenosis has to be taken, namely on structural homogeneity. Particularly in semi-arid, open, shrubby vegetation, such as the hillside vegetation of the Karoo, it often occurs that low trees and shrubs are scattered, singly or in small groups, over an open vegetation of dwarf shrubs and grasses. Under these low trees and shrubs certain smaller species occur, which are usually not found in the open dwarf shrub layer. One can regard such a vegetation as consisting of a mosaic of two vegetation types, a dwarf shrub and grass community and a low tree and shrub community. However, one can also regard it as consisting of one vegetation type. The latter stand is taken here for the following reason. If it was a mosaic of two communities, then one would expect to find locally more extensive homogeneous patches of either of the two communities. This is, however, never the case. The hillside vegetation represents apparently a stable ecological-sociological equilibrium, of different growth forms and thus constitutes one inseparable entity. That certain species only occur under the shrubs or low trees should be interpreted as a consequence of their specific ecological amplitude, and the occurrence of low trees and shrubs in the community, which change the microclimate and the local soil moisture conditions (compare Chapter II.2.9). However, the absence of more extensive homogeneous patches of such a vegetation of low trees or shrubs with specific understory strongly suggests that it does not constitute a vegetation type of its own and that the hillsides of the Karoo are not covered with a close mosaic of two communities but with one open shrub community. A similar structure was recently reported by OBERDORFER (1970) from the Canary Isles, whereas DAHL & HADAC (1949) interpreted, according to the same principles, a superficially similar structure from South Norway, as a mosaic of two communities.

In the present study, samples were taken such that each sample plot well represented the structure of the surrounding vegetation. Thus, the plot line often cut halfway through a small group of shrubs, rather than including virtually either a complete group of shrubs or the dwarf shrubs and grass vegetation only.

Another feature of structure in a phytocoenosis is stratification. Various vegetation layers can often be recognized in a phytocoenosis, sometimes clearly distinguishable from each other, other times hardly recognizable as separate strata. In the Zürich-Montpellier School it is believed that these strata are in mutual ecological interaction and cannot be considered to constitute separable and independent ecological units (BRAUN-BLANQUET, 1964; WESTHOFF, 1967, 1968; cf. BOERBOOM, 1960). There are exceptions to this rule, such as in the case of crustal lichen communities on tree trunks (cf. BARKMAN, 1958), because such communities do not root in the same substratum as the trees and other layers and in the case of aquatic communities (cf. DEN HARTOG & SEGAL, 1964; SEGAL, 1965; WESTHOFF, 1967; WESTHOFF & DEN HELD, 1969). However, the question of scale also plays a role here. In order to have a record of the structure of a sampled phytocoenosis, Zürich-Montpellier workers traditionally keep notes at each plot of the various vegetation layers distinguished, their ranges in height and an estimation of the aerial cover of each layer. Also an estimation of total aerial cover of the entire vegetation of the sample plot, including all strata, is recorded. This procedure was also applied in the present study. The various vegetation layers were not always clearly distinguishable, however, and strata labelled with a particular name, were not always of the same height at each sample plot. In the riverine forest and woodland a tree layer, shrub layer and field layer could always be clearly distinguished. In the other vegetation types maximally four layers were recognized: a tree layer; a low tree and shrub layer; a dwarf shrub and grass layer and a groundlayer The tree layer comprises trees over 5 m in height, whereas the low tree and shrub layer comprises trees less than 5 m tall and shrubs over 1 m high. The dwarf shrub and grass layer comprises dwarf shrubs, herbs and grasses usually less than 1 m in height, although some grasses, such as *Hyparrhenia hirta* were sometimes up to 1,5 m high. In such cases they are still included in the dwarf shrub and grass layer . The label "dwarf shrub and grass layer" is not meant to indicate that dwarf shrubs are always dominant or prominent in this layer, although this usually is the case. The groundlayer comprises creeping, trailing, prostrate and rosette plants. This layer is mainly less than 0,05 m high, although frequently some of the slender flowering culms of grasses exceed this height.

TÜXEN (1957) proposed a simple formula for comparison of the cover values of the various vegetation strata and thus the structure of vegetation samples. However, since in the study area the various layers were not always clearly separable this procedure could not be used.

The structure of the vegetation at each sample site was determined following the system of FOSBERG (1967). Although it is a system based on rigidly defined concepts (cf. WERGER, 1973a), it is applied here because it seems to be the most widely used modern system, and it is recommended by the International Biological Programme for the survey of conserved areas.

V.1.6 Floristic problems

At each sample site complete lists of the species occurring in the plot are drawn up. These can include vascular plants as well as mosses, hepatics, lichens, fungi, algae, etc. Since the later extraction of syntaxa in phytosociological tables is based on these floristic lists, it is of great importance that all species of the taxonomical groups considered, which are present in the plot, be recorded and that the plant individuals are correctly identified. The requirement of complete species lists cannot easily be met with in arid and semi-arid areas, since, depending on irregular rainfall, some geophytes and annuals might not be visible each year or at any particular time of the year. Complete species lists would thus require multiple visits of each quadrat site. The extent of the study area and the time available did not allow this, so that it was decided to emphasize permanently recognizable species. Thus, at each site all the species visibly present were recorded, but only permanently recognizable species were taken into account for tabulation. This meant that several geophytes and annuals were excluded from the phytosociological tables. The omission of these species was not felt to be a serious disadvantage, since the permanently recognizable species constitute a relatively rich flora.

With a few species taxonomical difficulties were experienced. Partly owing to the extreme richness of the South African flora, several taxonomical groups have not been revised for more than half a century. As a result, the species concept in certain groups is not always unequivocal, which makes pertinent identification impossible. The following taxonomical vaguenesses in the present study should be considered in this light. (1) No distinction was made between *Cotyledon decussata* Sims and *Cotyledon orbiculata* L., since no consistent difference between the two species could be found. Occurrences of any of these two species were listed and entered in the table under the label *Cotyledon decussata-orbiculata* complex. (2) Similarly, the species *Eriocephalus pubescens* DC. and *Eriocephalus ericoides* (L.f.) Druce have not been distinguished from one another. If these are clearly different species, it is likely that in the communities on Kalahari sand (viz. Chapter VI.6) not *Eriocephalus pubescens* but *Eriocephalus ericoides* occurred constantly. (3) Extremely difficult taxonomically is the *Eragrostis curvula* Nees - *Eragrostis chloromelas* Steud. complex. In the present study a narrow concept of *Eragrostis chloromelas* Steud. and a broad concept of *Eragrostis curvula* Nees is maintained. (4) Individuals indentified with the name *Nestlera humilis* Less. could clearly be separated into two forms, a grayish one, mostly occurring on calcrete, and a more bronze green coloured one. The gray form was recorded as *Nestlera humilis forma*, and the bronze green form as *Nestlera humilis*. (5) *Lycium salinicolum* is taxonomically not clearly delineated. In the present study a rather broad concept of the species is maintained. (6) The species *Tarchonanthus camphoratus* comprises a range from narrow leaved to broad leaved forms, which are in their extremes clearly distinct, but various intermediate forms exist. A broad concept of *Tarchonanthus camphoratus* has been maintained in the present study, including all these forms.

Although the Zürich-Montpellier system is based on floristics, this is not necessarily the only criterion for a detailed classification system of vegetation (cf. LANGFORD & BUELL, 1969). In an ordination study KNIGHT & LOUCKS (1969) used structural-functional characters, such as life form, leaf size, pollination mechanism, bark thickness, seed-dispersal mechanism, etc., regardless of species, to group stands of forest. Limitations of such an approach are that usually structural-functional characters are not as unanimously acceptably defined as species mostly are whereas, further, such an approach often requires a better autecological knowledge of species in the quadrat, than is available for the species of most areas.

V.1.7 Cover-abundance

The relative importance of each species in a quadrat is assessed on the wellknown cover-abundance scale in use by the Zürich-Montpellier School (BRAUN-BLANQUET, 1928, 1951; ELLENBERG, 1956; BECKING, 1957; SCHMITHüSEN, 1968; KNAPP, 1971). This scale, which is partly based on cover and partly on abundance, has received a good deal of criticism (BARKMAN et al., 1964). Cover refers to aerial cover, or the area covered when the canopy is vertically projected onto the ground. Cover and abundance are estimated. Although this is basically a subjective procedure, the estimates of different phytosociologists analysing the same patch of vegetation, prove to be amazingly similar, so that the procedure is not entirely haphazard (DAHL, 1957; VAN DER MAAREL, 1966b). The common cover-abundance scale reads as follows:-

r Very rare and with a negligible cover (usually just a single individual).
\+ Present but not abundant and with a small cover value (less than 1 per cent of the quadrat area).
1 Numerous but covering less than 1 per cent of the quadrat area or not so abundant but covering between 1 and 5 per cent of the quadrat area.
2 Very numerous and covering less than 5 per cent of the quadrat area, or covering between 5 and 25 per cent of the quadrat 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.

As shown above, scale-units 3, 4 and 5 only refer to cover, whereas the other scale-units can refer to cover and abundance. BARKMAN et al. (1964), argued that the steps in the scale are not proportional to one another and that the combination of abundance and cover in one and the same scale is in principle illogical. They criticized particularly the broad definition of scale-unit 2. Without altering the basic units of the cover-abundance scale, they advocated modifications by adding secondary symbols to the above-listed ones. This had the advantage of anabling more precise and narrower definitions of the scale-units, whereas floristic lists rated on their scale still allowed direct comparison with older ones rated on the traditional Zürich-Montpellier scale by simply disregarding the additional symbols. The scale of BARKMAN et al. (1964) appears, however, to be more suitable for detailed survey of permanent quadrats, and the like. Only their modification of scale-unit 2 was adopted in the present survey. Thus, in the present survey the above-listed cover-abundance scale was used with the following adaption of scale-unit 2:

2m Very numerous, covering less than 5 per cent of the quadrat area.
2a Covering between 5 and 12 per cent of the quadrat area independent of abundance.
2b Covering between 13 and 25 per cent of the quadrat area independent of abundance.

In the latest edition of his *Pflanzensoziologie* BRAUN-BLANQUET (1964) slightly changed the cover-abundance scale without giving reasons. Instead of the traditionally used lower limit of 5 per cent of scale-unit 2, he now takes 10 per cent as the lower limit. This is very disadvantageous as the traditional scale was used for about half a century and an extensive data collection has been built up. The new definition of scale-unit 2, which does not constitute an obvious improvement, can thus only be confusing and should be avoided.

V.1.8 Sociability

All species occurring in a quadrat are often also rated on the sociability scale, which is devised to indicate the grouping of individuals of the same species. For this purpose, any sprout coming out of the soil is regarded as a separate individual, regardless of whether it is connected with other individuals or not. The scale, which is "circular" rather than linear (cf. BARKMAN et al., 1964), reads as follows:-

1 Single individuals.
2 Grouped or tufted.
3 In troops, small patches or cushions.
4 In small colonies or extensive patches, or forming carpets.
5 In extensive crowds or pure populations.

As pointed out clearly by BARKMAN (1958), not the sociabilities of different species are compared, but the sociabilities of the same species in different habitats.

Many workers feel that sociability is a specific feature of each species and they regard it an unnecessary recording (e.g. ELLENBERG, 1956; BARKMAN et al., 1964), whereas others emphasize its importance and document how certain species have varying degrees of sociability under different ecological conditions and in different associations (MELTZER & WESTHOFF, 1942; PFEIFFER, 1962; BRAUN-BLANQUET, 1964).

VAN DER MAAREL (1966a, 1970) emphasized the correlation of the sociability of a species and its growth form, and used a modified sociability scale for studying vegetation structure.

The stand taken in the present study was that sociability is largely a character that is specific to each species. However, it was not completely disregarded, but periodically a complete species list was rated on the abovementioned sociability scale. These values are summarized into the end column of each phytosociological table.

V.1.9 Other analytic characters of the vegetation

Many other analytic characters of the flora and vegetation in a quadrat can be recorded, such as local frequency, density, vitality, phenology, growth and life form of the species, yield of the vegetation in the quadrat, and others. Some of these characters are more commonly used in detailed studies of permanent quadrats, or are more suitable for special purpose studies.

None of these characters have been used in the present study, however.

V.1.10 Habitat characteristics

At each quadrat site, habitat characteristics are noted. Such notes may be rather superficial or reach a high degree of detail and should generally be in correspondence with the purpose and scale of the survey and the time available. For instance, statistical' ecologists, who are usually more interested in plant-habitat correlations than merely in a multi-purpose classification system (cf. LAMBERT & WILLIAMS, 1962; LAMBERT & DALE, 1964), more often aim for a rather detailed habitat characterization. Also the phytosociological school of EMBERGER in Montpellier records habitat features in a considerable degree of detail, for which standard checksheets were developed (GODRON, 1968).

In the present survey habitat was recorded as follows:-

(a) After the locality of the quadrat was plotted on a 1 : 50 000 topographical map, its altitude above sea level was ascertained from the map.

(b) The geological identity of the substrate was established.

(c) Notes on the geomorphology of the quadrat area and its nearest surroundings as well as on its setting in the landscape were made.

(d) Slope angle and slope direction (aspect) of the quadrat area were measured with a hypsometer and a compass respectively.

(e) Notes on the exposure to direct sun radiation, prevailing winds, etc. of the quadrat area were made.

(f) Biotic influences such as trampling, overgrazing, clearing of trees, etc. were noted. Notes were also made on other animal activity such as termites, ground squirrels, etc.

(g) Soil depth down to 0,40 m was measured and when deeper, its depth was estimated down to 2 m.

(h) Periodically the soil profile was recorded.

(i) Soil texture and rockiness of the soil were determined and notes were made on the estimated quantities and sizes of gravel and rocks in the soil.

(j) A soil sample from the top soil, 0 to 0,20 m deep, was taken. Its pH in a 1 : 3 water solution was measured colorimetrically and its HCl-reaction tested. Occasionally soil samples of deeper soil layers were taken and tested similarly.

These data were not entered in the phytosociological tables, as sometimes done by Zürich-Montpellier workers, but summarized in the habitat descriptions of the various syntaxa given in Chapter VI. If certain habitat data were found to be irrelevant to the habitat description of syntaxa, as, for instance, there was often no clear altitude correlation with the occurrence of syntaxa, this was left unmentioned.

V.1.11 Relevé

Such a completed site record of species, their relative importance, other analytic characters of flora and vegetation and habitat notations is generally called a relevé.

An appropriate definition of the term relevé is given by GODRON (1968): "Le relevé est un ensemble d'observations écologiques et phytosociologiques qui concernent un lieu déterminé".

V.1.12 Number of relevés

There is no theoretical basis on which an exact number of relevés needed to survey an area adequately, can be assessed. The number depends entirely on the scale of the survey, the variety in the survey area and the degree of precision which one wants to achieve. Statisticians agree that a higher sampling intensity reduces the variance in the data more effectively than improved sampling precision (cf. GOODALL, 1970). The total set of relevés taken should as adequately as possible reflect the total variety in the study area. Even distribution of relevés over the study area usually ensures this. In exceptional cases, such as for example in the dune area of the southern Kalahari (LEISTNER & WERGER, 1973) there is so little variation in the study area and homogeneous phytocoenoses cover such extensive areas, that an even spreading of the relevés is not strictly necessary.

The statement by SHIMWELL (1971) that the total number of relevés collected is "usually less than the manageable number of 40" is meant to illustrate common practice in Europe and should not be interpreted as binding advice.

TÜXEN (1970b) emphasizes the importance of a large number of relevés for the compilation of a sound phytosociological classification system.

In the present study 561 relevés were taken in the study area, which measures slightly more than 3 000 km^2. This results in a sampling intensity of approximately 1 relevé per 5 km^2. The present study can thus be classified as semi-detailed (EDWARDS, 1972). The distribution of the relevés over the study area is shown in fig. V.1.

V.2 SYNTHESIS

After the field data have been sampled the synthetic stage of the survey follows, which should finally lead to correctly interpreted results. Several concepts and technical procedures used in the process of synthesis will be briefly elucidated below.

V.2.1 Tabulation

The compilation of phytosociological tables from field data has been described in great detail by ELLENBERG (1956), and English and French translations of that account have been published by KÜCHLER (1967) and GOUNOT (1969) respectively. SHIMWELL (1971) also discusses the tabulation procedures in English. Therefore, only a brief outline need to be given here.

The field data are entered into a matrix in which the rows represent species and the columns relevés. When this matrix is completed, the result is called the raw table. The next step is to study visually the association between species. Positive as well as negative association is important (TUOMIKOSKI, 1942). The matrix is rearranged, so that positively associated species are grouped together and apart from the general and the

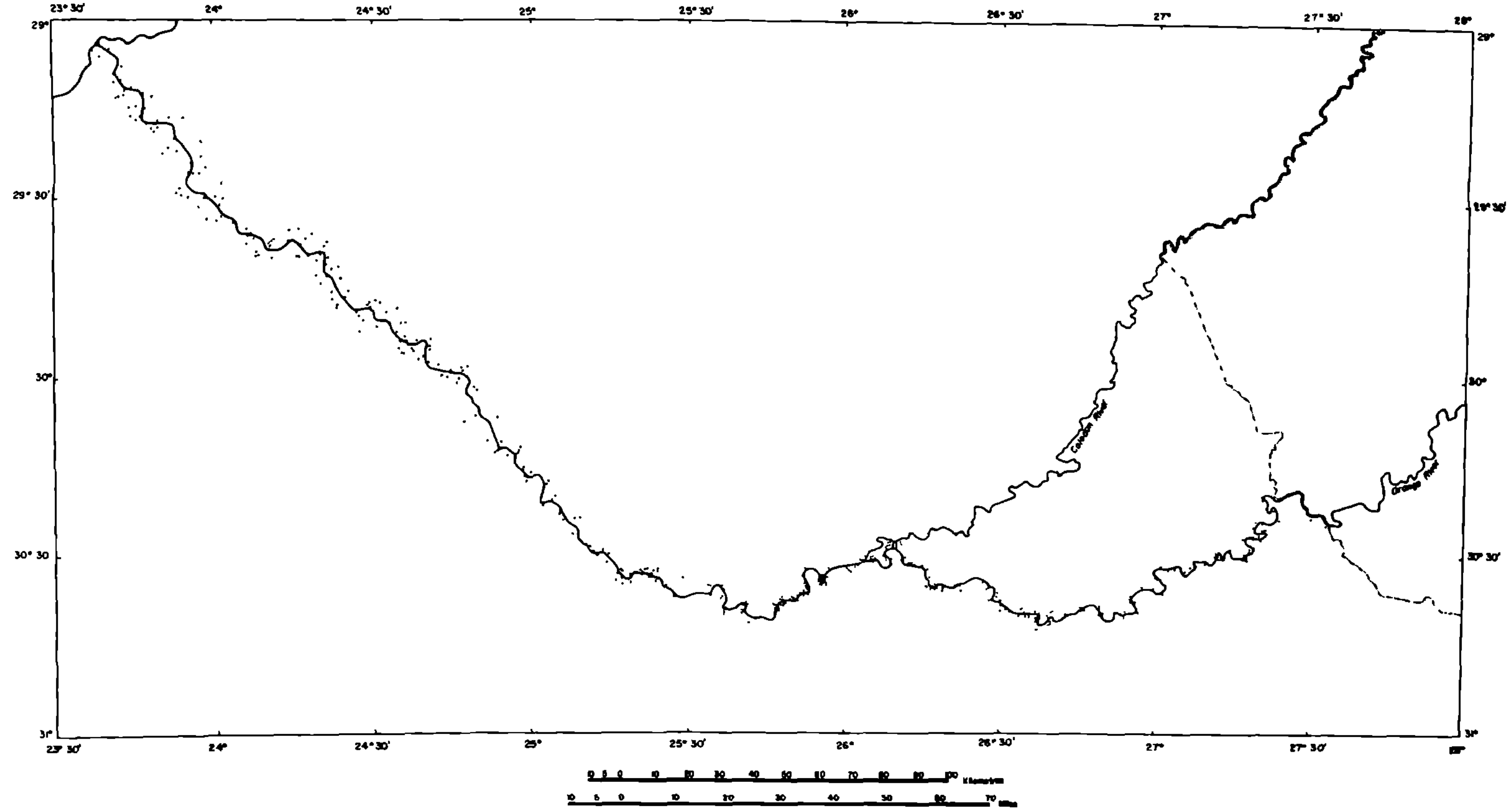


Fig. V.1 Distribution of relevés in the study area.

more infrequent species, which do not show clear discriminant floristic associations and are listed in the lower part of the table. Membership of a species to a species group is not necessarily determined by association with any individual species in that group, but can also be based on its restriction to the general distribution range in the table of a group of associated species. A second rearrangement of the matrix places the relevés with a strongly similar species content together. These successive rearrangements of rows (species) and columns (relevés) in the matrix should be continued until a clear pattern of mutually discriminant noda of species-relevé groups is obtained. This way of grouping species and relevés into species-relevé groups is in theory similar to taxonomical classification procedures in which, according to HULL (1964-65) "usually no one particular property or set of properties is necessary and any one of numerous sets is sufficient". WITTGENSTEIN (1960) originally discussed this classification process under the term "Familienähnlichkeiten" or family resemblances (cf. also GILMOUR & WALTERS, 1964; BAMBROUGH, 1966; KHATCHADOURIAN, 1966).

The process of rearranging a raw table into a final phytosociological table is largely objective, as has been emphasized by ELLENBERG (1956) and demonstrated by SPATZ & SIEGMUND (1970) and COETZEE & WERGER (1973). These latter authors carried out hierarchical syndrome analysis on Fynbos data, which had been used to construct phytosociological tables. The results of the analysis matched well with the structure of the tables. As already briefly mentioned in the previous chapter SPATZ & SIEGMUND (1970) developed a computer program to make phytosociological tables. They took data of ELLLENBERG (1956) and compiled a computer-made table, which was nearly identical to that made by hand by ELLENBERG (1956). This and several other computer-based methods might yield even better results, when quantity measures of absence similar to those described by SWAN (1970) are used. In the present study the apparatus described by MüLLER et al. (1972) was used for rearranging the raw table. The apparatus proved to be efficient, particularly in that it saved a considerable amount of time.

It is common practice to place the individual relevés within a nodum in a specific sequence. This sequence can be according to decreasing total number of species, according to any environmental gradient observed, or to any other varying character of the vegetation or habitat observed (BRAUN-BLANQUET, 1964). The prevailing feature of the present study area is the roughly east-west climatological, geological, geomorphological, pedological and vegetational gradient (compare Chapter II) and it was decided to arrange all relevés within the noda according to their geographical position east of Greenwich, starting with the easternmost relevé in the left hand side of a nodum, except for some relevés which proved to be transitional between two noda. Species are placed in order of presence in each nodum, in agreement with the common Zürich-Montpellier procedure.

Although in principle the results of the present survey could have been presented in one large table, this has not been done on practical grounds. Units, which strongly differ from one another in floristics have been presented in separate tables.

Much discussed is the question of whether or not to leave unrepresentative relevés out of the final table. Both sides have convincing arguments for their points of view. TüXEN (in lit.) for instance, argues that in surveys like the present one, the object is not so much to show all possible transitions and fragmentary forms in which an association can occur, but to describe syntaxa as clear and definite as possible. Heterogeneous, transitional and fragmentary relevés should thus be abandoned from the table. ZONNEVELD (1960) and GOUNOT (1969) on the other hand, strongly reject the practice of leaving "bad" relevés out of the table. According to GOUNOT, it is doubtful in such cases, if the table is not more an illustration of the author's preconceived ideas than a means of syntaxonomical research. He adds, however, that such practices do not at all invalidate the method as such, but just throw doubt upon certain results. Besides, it is felt by the present author, that retention of relevés which are less representative of a nodum than desirable, has in an initial study of an undescribed area, as the present one is, the advantage, that with later accumulation of data, such relevé data might prove valuable in that they might appear to represent a presently undersampled and not recognized syntaxon. In this context it is worthwhile to refer to WESTHOFF & DEN HELD (1969), who argue that once a proper syntaxonomical system is available, intermediate or transitional relevés are valuable, in that they give maximal information on the habitat of the vegetation to which they refer. These relevés indicate that the habitat of the vegetation concerned shows characters of each of the habitats typical for each of the communities that are mixed in the sampled phytocoenosis, namely in direct correspondence with the relative importance of each of the constituting communities.

In the present study it was decided not to reject transitional or unrepresentative relevés on prejudice. When specific relevés with reference to the total table appeared to be clearly heterogeneous, or their total number of species was so low that it evidently showed their fragmentary nature, these relevés were rejected for the table after having been interpreted. However, relevés were not omitted when they represented transitional stages between recognized table units. Thus, in two cases a relevé taken on the outer edge of the riverine woodland, so clearly contained a mixture of riverine and surrounding Karoo vegetation that they were rejected. Twenty further relevés were of such a fragmentary nature in floristic composition, obviously owing to extreme overgrazing and trampling, that, although they were ecologically interpreted, they were not represented in the tables.

V.2.2 Synthetic characters, character species, differential species

A finalized phytosociological table contains far more information than the sum of the information in each relevé (TÜXEN, 1970b). It displays part of the synthetic characters of a community. Since the species are arranged according to presence within the noda, the phytosociological table allows the assessment of which species are constants or dominants in a community at a glance. A number of species will occur constantly over the entire table, whereas others might be limited or virtually limited to one or a number of noda or table-units, which may after ecological confirmation appear to represent communities. Those species that are restricted in their occurrence, are faithful to one or more noda or possible communities. They may be called differential species, because they differentiate between noda (cf. ELLENBERG, 1956). This need not coincide with a high presence value within the nodum. Faithfulness to a community or certain communities is called fidelity and is a synthetic character. Besides presence, fidelity can also be based on cover-abundance, sociability and vitality values (PFEIFFER, 1962; BRAUN-BLANQUET, 1964; WESTHOFF & DEN HELD, 1969). As pointed out in the previous chapter, the Zürich-Montpellier School, following SZAFER & PAWLOWSKI, recognizes five degrees of fidelity: exclusive, selective, preferential, vague or indifferent and strange, Originally it was thought that most communities would contain exclusive species (cf. BRAUN-BLANQUET, 1915). When more data became available it appeared that more species were selective or preferential rather than exclusive. Exclusive, selective and preferential species were all called character species. Then the concept of differential species was introduced, first by KOCH (1925). It is a species which is preferential for a certain community and therefore distinguishes this community from other floristically related communities, but it is at the same time equally well or even better represented in still other communities. Differential species were initially only used to distinguish subassociations and variants of associations, but gradually it became common practice to use differential species also for the characterization of associations and higher syntaxonomical units (BECKING, 1957). TUOMIKOSKI (1942) pointed out that character species are but a special case of differential species. With the accumulation of data from various parts of Europe it became clear that few species are faithful to a specific community over its entire distribution area. Those species that are, are called absolute character species (BRAUN-BLANQUET, 1951; BECKING, 1957; WESTHOFF & DEN HELD, 1969; KNAPP, 1971; WESTHOFF & VAN DER MAAREL, 1973). When the distribution area of a species exceeds that of the association in which it is found, it often occurs that the species is faithful to a specific association in one part of its distribution area and to another vicarious association in another part. Such species are called territorial or regional character species (BRAUN-BLANQUET, 1951; BECKING, 1957; WESTHOFF & DEN HELD, 1969; WESTHOFF & VAN DER MAAREL, 1973).It often occurs, however, that certain species are only faithful in a limited part of the range of the association. These species are called local character species (BECKING, 1957; WESTHOFF & DEN HELD, 1969; OBERDORFER, 1968; KNAPP, 1971; WESTHOFF & VAN DER MAAREL, 1973). MEIJER DREES (1951) and BECKING (1957) elucidated these geographically based concepts of character species in clear diagrams. BECKING (1957) also took the relative size of the range common to association and species into account and pointed out that a species on the fringe of its distribution area can characterize an association significantly whereas the same species may be without diagnostic value in its optimal range. This is a very common phenomenom, with an obvious ecological explanation. In its optimal range a species will not be restricted strongly by specific, less favourable ecological conditions, while on the fringe of its distribution area, where the environment is rather unfavourable, it can only survive in a narrowly defined habitat.

In a later paper BECKING (1961) suggested distinguishing between faithful presence, faithful sociability and faithful vitality. He tried to define these concepts quantitatively, but this did not prove to be useful.

SCHWICKERATH (1944, 1954, 1968) has repeatedly attacked the concept of local character species and argued that from comprehensive studies, extended over the entire range of the association, these species would appear to be either true character species or geographical differential species. According to SCHWICKERATH, geographically varying character species, will still have a clear optimum over the entire range of the association, although this optimum may vary geographically. Geographical differential species occur only in a limited range of the association. They can be either largely restricted to a specific association, or they can be important in other associations as well.

Still another type of character species is formed by the transgressive character species. Such a species is characteristic of a syntaxon above the association level, for example an alliance, but at the same time it is more characteristic for a specific association within that alliance than for the other associations in the alliance (BECKING, 1957; WESTHOFF & DEN HELD, 1969).

Species which do not differentiate between communities are called accompanying or companion species. They can be constant as well as rare.

With the gradual broadening of the fidelity concept, it became more usual to characterize an association by differential species, and even by characteristic species combinations, although these practices are used with some restriction (BARKMAN, 1958; WESTHOFF & DEN HELD, 1969). Fidelity of species to associations can only be determined on the basis of phytosociological tables, using the method described by SCHWICKERATH (1931) in less evident cases, and associations are not "determined in the field because species of known narrow amplitude are present", reducing the later determination of faithful species to a circular argument, as POORE (1955, 1956) suggested. As pointed out by BARKMAN (1958), MOORE (1962) and GOUNOT (1969) this suggestion was based on a poor understanding of the Zürich-Montpellier approach and is entirely invalid.

The present survey does not cover the entire ranges of specific syntaxa and taxa. And being the first comprehensive study according to the Zürich-Montpellier approach in South Africa, virtually no additional data are available from other sources. Therefore, it could not be established whether specific character species are local, regional or absolute character species and only local character species and differential species have been distinguished. If species faithful to noda in the tables showed optima in more than one nodum, they were called differential species; otherwise, they were called (local) character species. Species which were concentrated in more than one nodum, but had clearly their optimum in one specific nodum, were called (local) character species for the nodum in which they reached their optimum, and differential species for all other noda in which they were concentrated, as against the other noda from which they were absent or virtually so. In the tables as well as in the descriptions of the syntaxa in Chapter VI differential species are indicated by (d). Since, as pointed out, the present study does not cover complete ranges of taxa and syntaxa and no data are available from the areas adjacent to the study area, the determination of species as character species remains to a certain extent a presumption. This uncertainty is minimal, however, because most associations have been sampled over the entire mesic-xeric gradient existing in east-west direction in the study area and constituting the most important gradient there (compare Chapters II and VII). The associations occurring at either ends of the study area, particularly the Rhammo-Rhoetum and the Melhanio rehmannii-Hermannietum spinosae, have not been sampled over the entire above-mentioned gradient. Therefore, some species typifying these associations and occurring only in these associations within the study area appear to be character species but in reality are only differential species, because they also occur frequently just outside the study area in other communities which have not been sampled. Based on such observations some species, mainly of those typifying the Rhammo-Rhoetum and the Melhanio rehmannii-Hermannietum spinosae, have been distinguished as differential species and are indicated in the tables by (d).

Another synthetic character is the average number of species of a community. The total number of species in each relevé is entered in the heading of the table and, when these figures are more or less similar for all relevés within one community, this is an indication that the community-table is more or less homogeneous. Table homogeneity is called homotoneity in recent literature (DAHL, 1957; cf. WESTHOFF & VAN DER MAAREL, 1973). Hence, the absolute value of these figures is theoretically unimportant. Just the deviation of the value for each relevé from the average is important, in that it indicates to what extent each relevé is floristically representative of the entire community (KNAPP, 1971). A complicating factor concerning the matter of average number of species is, of course, the number of species that are common to all relevés in a community or to only a limited number of relevés or not even common to two relevés in a community (cf. TÜXEN, 1970c). At the moment there is no agreement on the theoretical implications of the homotoneity of a community-table (see, for example, the discussion following TÜXEN's (1970c) exposé on the subject).

In the present study the average numbers of species, as given in Chapter VI, are calculated from the total numbers of species in relevés which were subjectively selected as floristically representative. Hence, relevés with exceptionally low or high total numbers of species were excluded from the computation of the average. Furthermore, the average numbers of species are based on total numbers of permanently recognizable species (see above). Therefore, it should be emphasized that no more value and significance should be given to these figures, than that they serve as a preliminary standard for judging the relative floristic agreement between the relevés and the communities to which they belong.

Also the structure of the community can be regarded as a synthetic character. This will be discussed below.

V.2.3 Ecological confirmation of the table pattern

The arrangement of species and relevés in the phytosociological table is not an aim in itself, but should lead to a comprehensive classification system of syntaxa, that can serve as the basis for further ecological studies (BRAUN-BLANQUET, 1964; IVIMEY-COOK & PROCTOR, 1966; TÜXEN 1970b). When the noda in the phytosociological table are established, their biological reality should be confirmed by means of demonstrating coincidence between the community-types which they possibly represent and specific habitat conditions. The checking of the ecological meaning of a supposed community can be done in the field, or from the habitat characterization of the relevés on the field sheets. Should this latter approach be used, final checking in the field is still a necessity.

Confirmation of coincidence between the pattern on the phytosociological table and specific habitat conditions is necessary for the following reason: All taxa have their ecological amplitude, within which they can survive, and outside which they cannot exist. Species that have a high presence over the entire phytosociological table presumably have an ecological amplitude that is at least as wide as to include all habitats of the relevés making up the table. Character and differential species, however, have a smaller ecological amplitude, at least in the area where the relevés were taken. Their ecological amplitude is such that it does not allow the species concerned to exist in some of the habitats of the relevés comprising the table. Because the central concept of all approaches based on the community-unit theory implies that vegetation consists of basic natural entities which generally contact one another along narrow boundaries, it is supposed that when the ecological amplitudes of some species at least on one side more or less coincide, such a narrow boundary occurs. Hence, if the coincidence of certain habitat conditions and a nodum section in the table can be confirmed, a basic vegetation unit, a community, is delineated. Species, as indicators of a certain habitat and typical of a community, are thus indicators for the habitat typical of a community. This is also expressed by VON GLAHN (1968) when he says that the vegetation type is "das maximale korrelative Konzentrat wiederholt vorkommender Artenverbindungen und bestimmter Merkmalskombinationen seines Standortes." In this way it is proved that the pattern in the table is not an artificial one due to a clever manipulation of the matrix rows and columns, but represents real, floristically and environmentally characterized natural entities.

In the Zürich-Montpellier approach, a parallelism between floristic and ecological variation is thus not just a priori postulated. The method empirically determines that differences in floristic composition correspond with differences in the environment (GOUNOT, 1961, 1969).

V.2.4 The association and other syntaxa; constancy table

The definition, proposed by SCHRÖTER & FLAHAULT and accepted by the Third International Botanical Congress in Bruxelles in 1910, of the basic natural community of the Zürich-Montpellier system, the association, was given in Chapter IV. A plant community thus has a definite floristic composition, a uniform physiognomy and is bound to uniform habitat conditions. Although special weight was and is given to character species and later to differential species, the association is not solely based on these species, but on its total floristic composition (BRAUN-BLANQUET, 1915, 1959, 1964; WESTHOFF & DEN HELD, 1969).

Associations are subdivided into subassociations, variants and facies. Subassociations and variants are characterized by their own differential species and have their specific habitat mostly varying only in subordinate features from the habitat of other subassociations in the same association. A facies is characterized by the strong dominance of a specific species and possesses no character or differential species of its own (ELLENBERG, 1956; BRAUN-BLANQUET, 1964).

Associations are combined into alliances, alliances into orders and orders into classes. Alliances and orders have their own character and differential species; classes are distinguished on the basis of character species only (BRAUN-BLANQUET, 1964). An useful tool in the procedure of hierarchisation is the so-called Roman or constancy table (although based on presence). For each species the presence within each community is rated on a five-point scale and the range of its cover-abundance value is noted:-

I	Species present in 1 to 20 per cent of the relevés of a community.
II	Species present in 21 to 40 per cent. of the relevés of a community.
III	Species present in 41 to 60 per cent of the relevés of a community.
IV	Species present in 61 to 80 per cent of the relevés of a community.
V	Species present in 81 to 100 per cent of the relevés of a community.

Each community is thus reduced to a single column in the Roman table and species faithful to the various communities are easily assessed.

With the development of the concepts of character and differential species, the concept of the association was also somewhat modified. Whereas according to certain authors, the association should still possess character species (SCHWICKERATH, 1954, 1968; BRAUN-BLANQUET, 1964; OBERDORFER, 1968), others recognize in exceptional cases associations, which have only differential species or only a characteristic species combination (DOING KRAFT, 1956; MAAS, 1959; BARKMAN, 1958; WESTHOFF & DEN HELD, 1969). Many association character species are only local or regional character species. According to OBERDORFER (1968) every association is therefore at the same time a regional or geographical association (Gebietsassoziation). If in different areas of the regional association differences occur in the species combinations of accompanying or also order and class character species, while the floristic composition of the group of association and alliance character species remains unaltered, one should distinguish geographical races of the association. If, however, the floristic composition of the group of alliance and association character species alters, different geographical associations should be distinguished (OBERDORFER, 1968). BORHIDI (1963) suggests the combination of regional associations into synassociations, which would rank between regional associations and suballiances. SCHWICKERATH (1954, 1968) only wants to recognize geographic subassociations of an association, and, as pointed out above, argues that most species, which are called local character species at present, will finally prove to be geographical differential species, whereas a few others will prove to be true character species. KNAPP (1971) accepts the idea of geographical associations and suggests the combination of them into chief associations (Hauptassoziationen) or association groups (Assoziationsgruppe). As pointed out by WESTHOFF & DEN HELD (1969), several authors have recently regarded geographical associations as the real associations and promoted the chief association simply to alliance. This is one of the practices which can lead directly to what PIGNATTI (1968) calles "the inflation of higher syntaxonomical units". Particularly in floristically rich vegetation the concept of an association can differ strongly from worker to worker. For instance, RICHARDS (1954) regards the floristic, edaphic and climatic factors in the Mixed Rain Forests from Guinea to Uganda to such an extent homogeneous, that according to him, this community forms a single association over the entire area. POORE (1964) on the other hand, considered very few uniform sites large enough to contain a representative part of the rain forest in Malaysia and interpreted the forest vegetation as consisting of a large number of association fragments in the sense of the Zürich-Montpellier School.

In the present study all communities characterized clearly by a group of species labelled "character and differential species", and identified with specific environmental conditions which differ from other communities, were regarded as associations in the proper sense. One association is recognized, which is typified by a large group of differential species only. Some minor communities were not given any syntaxonomical rank, since the data available for these communities were considered insufficient. Also the eastern grassland communities were not given rank for reasons mentioned in Chapter VI.2. Subassociations and variants were distinguished on the basis of differential species which usually had a wide-spread occurrence outside the syntaxa concerned. Variety in environmental conditions corresponds with this occurrence of differential species. Facies were not distinguished. Alliances and orders were recognized on the basis of character and differential species; classes on character species. Usually the hierarchy was not further described than necessary for the explanation of vegetation interrelationships in the study area. In two cases this principle was departed from and provisionally alliances were proposed, which had the advantage that large, floristically similar areas could be delineated.

V.2.5 Nomenclature

No international accepted nomenclatural code for syntaxonomical use exists as yet, although particularly since the early fifties (cf. MORAVEC, 1969) several attempts have been made to achieve this aim. WESTHOFF & DEN HELD (1969) point out, that one of the main reasons for the persistent failure to reach an international agreement is that the type-method as used in taxonomy, and advocated for syntaxonomical use by BARKMAN (1958) and MORAVEC (1968), is not suitable, in that it is hardly possible to designate generally acceptable type-relevés. Another difficulty results from a taxon name being meant as a label without any diagnostic function, whereas the name of a syntaxon refers to one or more species occurring in it. Although a strict priority rule is often difficult to apply priority is generally recognized as far as possible. Tentative rules were published by MEIJER DREES (1954) and were commented upon by several workers in the same issue of *Vegetatio*. More recently MORAVEC (1968) published a renewed design for a nomenclatural code, which comprised several of MEIJER DREES' proposals. The suggestions of MORAVEC (compare also MORAVEC, 1969, 1971), which seem to have received considerable approval, deal with:-

a) conditions for the effective and valid publication of a name;
b) sufficiency of the added diagnosis;
c) typification of the name;
d) priority;
e) retention, rejection and alteration of names;
f) citation of authors' names.

In the Zürich-Montpellier School syntaxa are traditionally named after one or two taxa, adding an appropriate suffix, indicating the rank of the syntaxon concerned, to the name of the genus (BRAUN-BLANQUET, 1928, 1951, 1964). These suffixes are -etosum, -etum, -ion, -etalia and -etea for subassociations, associations, alliances, orders and classes respectively. If desirable the specific epithetet can be added in genitive. Detailed linguistic guides for the correct formation of syntaxonomical names have been published by BACH et al. (1962) and particularly by RAUSCHERT (1963).

Originally it was suggested that only character species be used for naming the associations, but this proved untenable (cf. MORAVEC, 1969). The only requirement that can be made at present is that the name-giving taxon must at least be present in the syntaxon concerned. In the present study syntaxa were mostly named after one or two of the taxa listed in the group of character and differential species. Sometimes a prominent or constantly abundant species was used in combination with a species of the character and differential species group to designate a syntaxon. The terms "inops" and "typicum" for subassociations were used following WESTHOFF & DEN HELD (1969). Apart for the rules of typification, the procedures worked out and discussed by BACH et al. (1962), RAUSCHERT (1963) and MORAVEC (1968) were followed.

V.2.6 Community structure

The definition of the association as accepted in Bruxelles in 1910 (see above) implies, amongst other requirements, that the association should be of an uniform physiognomy. Thus, it is to be expected that each association and subassociation described in Chapter VI, will comprise relevés which all belong to the same formation class, formation or subformation, as determined according to FOSBERG's system (1967). In a number of cases this will appear not to be true, however, particularly in the associations and subassociations of the Pentzietea incanae and the Stipagrostion (Chapters VI.5 and VI.6). The reason for this failure of structural homogeneity might be twofold.

Firstly, the rigidity of FOSBERG's system very often causes the classification of two relevés belonging to the same association or subassociation into two formations (cf. WERGER, 1973a). This is due to the degree of openness of the vegetation, which is rigidly defined, leading already to different formation classes. In the semi-arid vegetation types of the Upper Orange River area often only a minor difference in the vegetation leads to an alternative decision on the question "does the vegetation dominate the landscape, or does the substratum dominate the landscape?" of the FOSBERG key. The same applies to questions like "Shrub layer open or shrub layer sparse?" Moreover, the shrub layer comprises deciduous shrubs, which can be either thorny or not so, as well as evergreen sclerophyllous shrubs. These shrubs can each be dominant in specific phytocoenoses, without bringing about significant floristic differences, but leading to different formations or subformations in FOSBERG's (1967) system. In another sense these phytocoenoses are structurally homogeneous in that they consist of an open to very open shrub layer, an open dwarf shrub and grass layer and a sparse groundlayer. Hence, it might be concluded that part of the failure to meet the requirement of structural homogeneity is due to the rigidity of the structural criteria and is thus an artificially made failure.

The second reason for structural heterogeneity within some associations and subassociations described below is that some phytocoenoses recorded in the relevés possessed a shrub layer in addition to the dwarf shrub and grass layer and the groundlayer of other phytocoenoses. This is apparently related to the phenomenom of twin formations as discussed by WESTHOFF (1967, 1968), who adopted the term from nineteenth century publications by HULT and by KATZ. WESTHOFF (1967, 1968) elaborates on a number of examples where structurally different variants, subassociations or associations are combined into the same higher syntaxon because their floristic composition is strongly related. According to the floristic principle of the Zürich-Montpellier School these syntaxa could not equally well be classified in other, structurally more similar syntaxa. WESTHOFF (1967, 1968) observed that these twin formations only occur where extreme habitat factors predominate. Such extreme habitat factors are usually abiotic, for example extreme temperatures, frequent burning and a strongly fluctuating water table, according to WESTHOFF, and are to such an extent overriding that vegetation structure is in such places ecologically of relatively low importance. Structure should thus not be overestimated as a diagnostic criterion in such situations and floristic criteria should normally prevail (WESTHOFF, 1967, 1968).

As pointed out in Chapter II.6 the vegetation of the Upper Orange River area has been under influence of heavy overgrazing, which has led to a strong increase of shrub growth, particularly of species like *Rhigozum trichotomum*, *Acacia mellifera* subsp. *detinens* and *Acacia tortilis* subsp. *heteracantha*. These three species are always, by far, the main constituents of the shrub layer in cases where relevés with and without shrub layer are included in the same association or subassociation. Overgrazing and severe trampling can also be regarded as extreme habitat factors. It seems, therefore, entirely justified, that, like in VAN DONSELAAR's (1965) study of Suriname savannas, the floristic principle has prevailed in the present study, and that, contrary to the views of for example DANSEREAU & ARROS (1959), the communities described in the present study can be regarded as "good" associations and subassociations, despite their relative structural heterogeneity.

The higher syntaxonomic units described in the present study, such as orders and classes, are on another scale, structurally homogeneous and would allow a structural classification similar to the one attempted by WESTHOFF (1967). If a presumption is allowed on the basis of so small an amount of data, the structural similarity between both of the classes described so far supports the idea of DOING (1956, 1966) and PASSARGE (1966) that classes can be combined in structurally defined chief formations (Hauptformationen).

V.3 DEFINITION OF STUDY AREA

The valley of the Upper Orange River, from where it crosses the border between Lesotho and the Republic of South Africa near Palmietfontein, down to its confluence with the Vaal River at Mazelsfontein, constitutes the study area. As mentioned in Chapter II.1, this amounts to a length of 656 km, measured along the riverbed. Theoretically the valley was delineated as follows: Where the river cuts deeply through a plateau the valley could easily be determined as from the edges of the plateau. In strongly dissected areas, the valley was delimited following the highest ridges in the vicinity of the river, such that the study area still included the areas which drained directly or virtually so into the Orange River. In the flat area downstream of Petrusville, the outer edges of the valley were taken as the highest points in the slightly convex landscape.

In practice, however, the study area was usually taken wider than the theoretically delineated valley. Relevés were made on the plateau, outside the edges of the valley, and up to about 10 km away from the actual river course in flat areas. Hence, the survey included the vegetation which was no longer influenced directly by the river and by the landforms determined by the river. Taken as such, the study area measured slightly more than 3 000 km^2.

VI. THE PLANT COMMUNITIES

VI.1 THE RIVERINE COMMUNITIES (DIOSPYRION LYCIOIDIS)

True vascular waterplant communities are virtually absent from the Orange River and its tributaries, probably due to the high silt load of the water, although the large, sudden floods of these rivers might also be an important factor in this respect (BUTCHER, 1933; EDWARDS, 1969). An inventory of waterplants occuring in the catchment area of the Orange River upstream of Hendrik Verwoerd Dam drawn up by NEL (1972) revealed that thick and extensive floating mats of *Azolla filiculoides* Lam., a species known to be able to reproduce vegetatively at a vast rate (SCULTHORPE, 1967; MOORE, 1969), occur periodically in the Broekspruit, Bossiespruit, Brakspruit and a few other minor tributaries of the Orange River in the vicinity of Bethulie. At present, floating islands of this species, measuring up to 5 m in diameter, occur irregularly spread over the Hendrik Verwoerd Dam. A few other vascular waterplant communities in the Upper Orange River area are found in the small water reservoirs on farms. The most common of these is a community consisting of nearly pure stands of *Potamogeton pusillus* L. (NEL, 1972; EDWARDS & NEL, 1972).

Where dolerite dykes cross the river, rocky outcrops which are just above the waterline when the river is at low level, occur in the streambed. On these outcrops one regularly encounters extremely open stands of the loganiaceous shrub *Gomphostigma virgatum* (L.f.) Baill.

During the low water season numerous small to extensive sandbanks occur in the riverbed. Here temporary communities, in which neophytes can be important, become established. Among the most common species are (neophytes are indicated with (n); cf. HENDERSON & ANDERSON, 1966): *Agrostis lachnantha, Polygonum lapathifolium* subsp. *maculatum, Conyza podocephala, Erigeron floribundus* (n), *Salsola kali* (n), *Xanthium strumarium* (n), *Xanthium spinosum* (n), *Tagetes minuta* (n), *Bidens bipinnata* (n), *Aristida curvata, Chloris virgata, Argemone subfusiformis* (n), *Verbena officinalis* (n). On slightly more stabilized soil, and where the levees drop away into the river channel, these species also occur, together with *Senecio burchellii, Cynodon hirsutus, Mentha longifolia, Panicum laevifolium, Oenothera grandiflora* (n), *Oenothera rosea* (n), *Oenothera indecora* (n), *Chenopodium ambrosioides* (n), *Aristida junciformis, Eragrostis curvula, Cyperus esculentus, Artemisia afra,* and others. Trees and shrubs of *Salix capensis, Salix babylonica* (n) and *Nicotiana glauca* (n) and open to dense stands of *Phragmitis communis* are also often encountered here. The special adaptation of these plants to their habitat, which is subject to flooding, silting and alternately dry and wet conditions is discussed by AMBASHT (1968) in a paper on a floristically similar community on the banks of the Ganges.

Well developed levees occur along nearly the entire Upper Orange River. Only were the river cuts a steep valley through a dolerite dyke or other hard rock, such as locally between Hopetown and Douglas, where it cuts through the Ventersdorp lava and through the hard Molteno sandstone in some places in the Herschel District, are these accumulations of fine sand alongside the stream channel absent. On the levees, which can be up to 250 m wide, the forest and scrub, often refered to as "Mimosa-forest" by the early travellers, is found.

In the entire area from the Lesotho border to a few miles downstream of Colesberg the characteristic association on the levees is the Rhoo-Diospyretum ass. nov. (table Vl.1.1). Particularly characteristic for this association is the shrubby tree *Rhus pyroides* which is a constant character species and usually scores high cover-abundance values. Other character species of the Rhoo-Diospyretum are the grass *Bromus willdenowii*, the climbing herb *Rubia cordifolia*, the herb *Cineraria lobata* and the shrub *Melianthus comosus*. Differential species of this association against the Zizipho-Acacietum karroo are the spiny shrub *Asparagus suaveolens* and the grass *Melica decumbens*. Two subassociations of the Rhoo-Diospyretum occur in the Upper Orange River area. In the section between the Lesotho border and the vicinity of Norvalspont the subassociation celtidetosum subass. nov. is found, typified by the tree *Celtis africana* and in the lower layers *Achyranthes aspera*, *Pentarrhinum insipidum*, *Conyza podocephala* and *Artemisia afra* (table Vl.1.1). Between Norvalspont and the western limit of the Rhoo-Diospyretum, downstream of Colesberg, the subassociation acacietosum karroo subass. nov. occurs. Differential species of this subassociation is the tree *Acacia karroo* (table Vl.1.1).

In the western most range of the celtidetosum, between Goedemoed and Norvalspont, the *Acacia karroo* - variant occurs, in which the differential species of the celtidetosum as well as *Acacia karroo* are present. A preliminary description of this variant was given by WERGER (1973a) under the name *Acacia karroo-Celtis africana* Community.

The average number of species of the Rhoo-Diospyretum celtidetosum is 13, of the *Acacia karroo* - variant of this subassociation 14 and of the subassociation acacietosum karroo 12.

In the remainder of the Upper Orange River valley, and even further downstream to the vicinity of Aughrabies Falls, the levees are covered by the Zizipho-Acacietum karroo ass. nov. Character species of this association are the trees *Ziziphus mucronata* and *Rhus viminalis*, the shrub *Lycium austrinum*, the herb *Senecio burchellii* and the grass *Setaria verticillata*, whereas the grasses *Schismus barbatus* (d) and *Brachiaria marlothii* (d) and the hemiparasite *Viscum rotundifolium* are differential species of the association against the Rhoo-Diospyretum (table Vl.1.1). *Acacia karroo*, which also occurs in similar quantities in part of the Rhoo-Diospyretum, can only be regarded as a constant and prominent companion species in the Zizipho-Acacietum karroo. The average number of species of the Zizipho-Acacietum karroo is 10. A community that is floristically rather similar to the Zizipho-Acacietum karroo is mentioned by MOSTERT (1958) under the name "Valley *Acacia* Bush Community". LEISTNER (1967) and LESER (1971, 1972) reported a river fringing woodland or thicket with *Acacia karroo* and *Ziziphus mucronata* from the upper parts of the Auob in South West Africa, and LEISTNER (1967) reported also such a community from the upper reaches of the Nossob, Molopo and Kuruman in the southern Kalahari.

The Rhoo-Diospyretum and the Zizipho-Acacietum karroo have a number of constant species

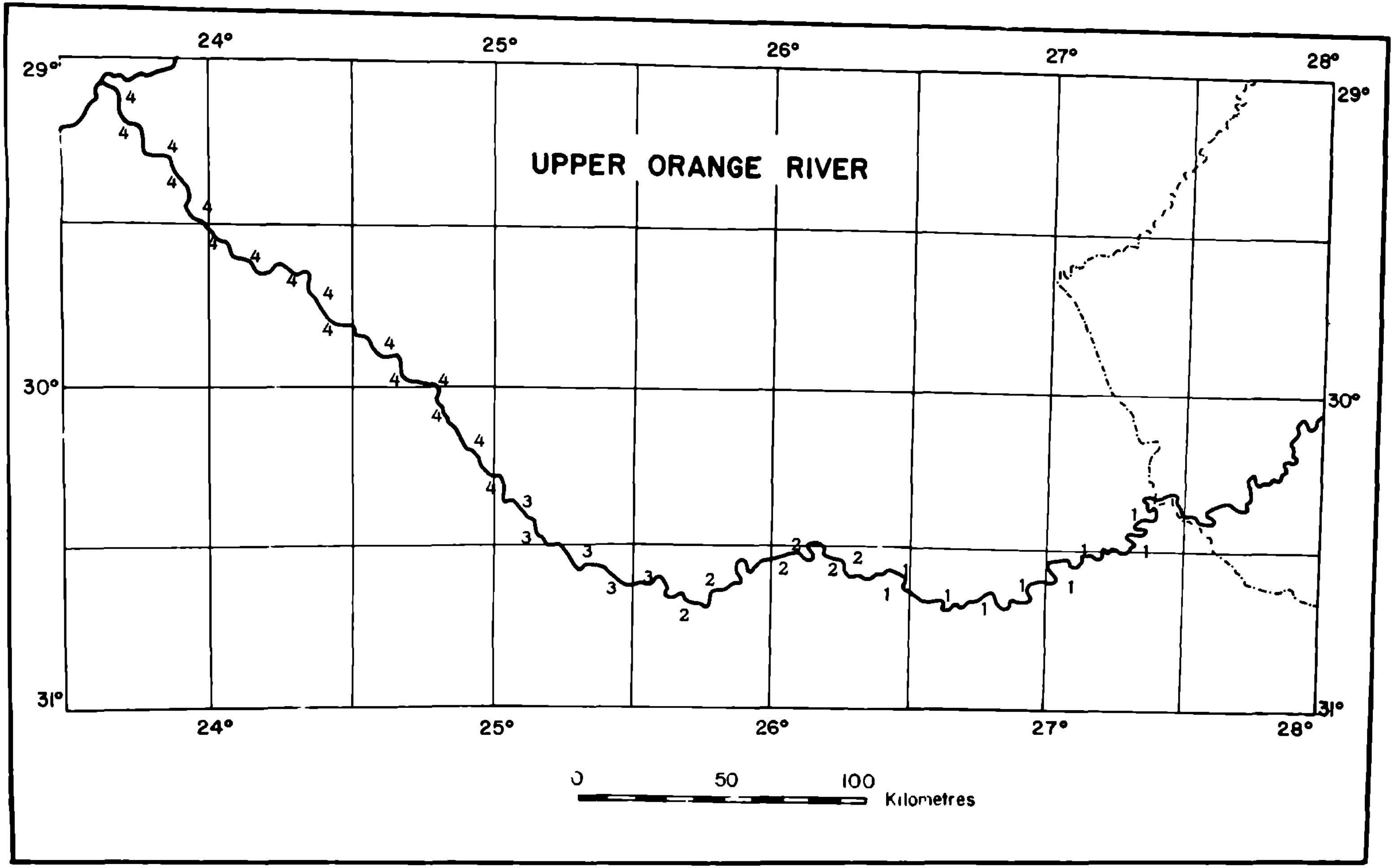


Fig. VI.1 Distribution of Diospyrion lycioidis in the study area. 1. Rhoo-Diospyretum celtidetosum; 2. *Acacia karroo*-variant of Rhoo-Diospyretum celtidetosum; 3. Rhoo-Diospyretum acacietosum karroo; 4. Zizipho-Acacietum karroo.

in common and are combined into one alliance the Diospyrion lycioidis all. nov. The following species are character species of the Diospyrion lycioidis: the shrubs *Diospyros lycioides* subsp. *lycioides, Lycium hirsutum* and *Lycium arenicolum,* the climbers *Asparagus setaceus* and *Clematis brachiata* and the neophytic herbs *Atriplex semibaccata* and *Chenopodium murale. Diospyros lycioides* subsp. *lycioides* usually reaches high cover-abundance values (table Vl.1.1).

Infrequently the two associations contain, apart from the above mentioned species, a few accompanying species of which *Nicotiana glauca, Hebenstreitia integrifolia* and *Salsola glabrescens* are the most regular but still not frequent. Intruding species of the surrounding vegetation, particularly of the Karoo dwarf shrub vegetation , are found more often in the two associations of the Diospyrion lycioidis. The commonest of these Pentzio-Chrysocomion species (comp. Chapter Vl.3) are *Aster muricatus, Chrysocoma tenuifolia, Eragrostis lehmanniana, Walafrida saxatilis* and *Pentzia globosa.* Thus, all constant species in the riverine forest and woodland are character or differential species for the various syntaxa and there are no constant accompanying species. In the more humid, temperate areas of the world this phenomenon is usually typical for syntaxa bound to extreme habitats, which represent, as such, exceptional cases. From a general ecological viewpoint, the levees, on which the Diospyrion lycioidis communities occur, cannot be considered extreme habitats. However, they represent an exceptional situation in the generally extreme ecological conditions of all surrounding ecosystems. It is possibly the exceptional situation of the riverine communities, which brings about the lack of constant accompanying species.

The vegetation of the Rhoo-Diospyretum and the Zizipho-Acacietum karroo is usually three layered. Often the tree layer of 6 to 10 m high reaches cover values of between 60 and 90 per cent, but this figure can also be considerably lower mainly due to cutting by man. The shrub layer, varying in height from about 1 to 4 m, usually covers less than 40 per cent, but the shrub layer can cover considerably more than 40 per cent, particularly when the tree layer is open. The cover of the groundlayer which is up to 0,70 m high, varies greatly, depending on biotic factors such as grazing and trampling. Total cover in both associations of the Diospyrion lycioidis is usually between 90 and 100 per cent. In FOSBERG's classification (1967) the Rhoo-Diospyretum belongs to formation 1A2.1, winter-deciduous forest, or 1D2.1, open deciduous orthophyll forest, whereas the Zizipho-Acacietum karroo belongs to formation 1A2.5, deciduous thorn forest, or 1D2.4, open deciduous broad sclerophyll forest.

Towards the sides of this fringing forest, where there is more light penetration into the lower strata, *Lycium hirsutum* and *Lycium arenicolum* tend to occur more abundantly than under the tall trees of *Celtis africana, Acacia karroo* or *Ziziphus mucronata.* Sometimes dense thickets of these spinous solanaceous shrubs occur. Also in open spots where farmers have cut away the large trees, as in the case of relevés 42 and 114, thickets of *Lycium arenicolum* in particular can be observed.

The distribution pattern of the syntaxa of the Diospyrion lycioidis in the Upper Orange River valley shows a clear geographic gradient from east to west: from the Lesotho border to the vicinity of Goedemoed the typical form of the Rhoo-Diospyretum celtidetosum occurs; from the vicinity of Goedemoed to the vicinity of Norvalspont the *Acacia* *karroo* - variant of this syntaxon is found; from there to a few miles downstream of Colesberg the Rhoo-Diospyretum acacietosum karroo is found, and from there onwards the Zizipho-Acacietum karroo covers the levees (fig. VI.1). The soil of the levees of the Upper Orange River over this whole range is of the same fine sandy type, over 3 m deep and with a neutral pH. The distribution of the various geological strata also does not correlate with the distribution of the syntaxa. Therefore, the likelihood of a distribution pattern due to a gradient in climate is an obvious conclusion. As described in Chapter II.2 there exists a gradient from east to west of decreasing mean annual relative humidity at 1400 S.A.S.T. and precipation in the area, as well as a gradient of increasing temperature, evaporation and mean saturation deficit at 1400 S.A.S.T. This gradient is reflected in the leaf structure of the vegetation layer that is most exposed to these macroclimatic factors, viz. the tree layer. In the eastern part of the area the prevailing tree is *Celtis africana* with leaves of a mesic type, followed westward by *Acacia karroo* with microphyllous leaves of a less mesic type and finally *Ziziphus mucronata* with coriaceous leaves becomes an important tree. In the lower layers there is not such a difference in leaf types between the various syntaxa, because the riverine forest is everywhere fringed on the sides by relatively dense scrub, which keeps the conditions inside the forest mesic (POTZGER, 1939). The climatological classifications according to WALTER & LIETH (1960) and UNESCO-FAO (1963) correlate well with the distribution pattern of the syntaxa of the Diospyrion lycioidis (compare Chapter II.2.8). WALTER & LIETH's zone II3a covers the area of the typical form of the Rhoo-Diospyretum celtidetosum, and their boundary between zones II4a and II(III)a coincides with that between the Rhoo-Diospyretum and the Zizipho-Acacietum karroo. UNESCO-FAO's intermediate temperate tropical zone covers the entire Rhoo-Diospyretum celtidetosum, the accentuated temperate tropical zone the Rhoo-Diospyretum acacietosum and the attenuated sub-desert zone the Zizipho-Acacietum karroo. The borderline between the typical form of the Rhoo-Diospyretum celtidetosum and the *Acacia karroo* - variant of this subassociation seems to coincide with the 500 mm isohyet.

STORY (1952) discussed the ecology of *Acacia karroo* in detail. His conclusion, that the species is absent from areas where the average absolute minimum temperature of the coldest month is less than 20°F (-7°C), seems to be confirmed by its distribution pattern along the Upper Orange River, but his statement, that the species is also absent where the precipation drops below 15 inches (381 mm) does not agree with the present findings. It may be significant in this respect, that presumably several ecotypes of *Acacia karroo* occur in South Africa, which makes ecological generalisation rather difficult (compare ROSS, 1971).

Like *Acacia karroo, Ziziphus mucronata* is a widespread species in South Africa. It clearly has its optimal presence and cover-abundance in the Zizipho-Acacietum karroo, but it is found also as a differential species in two other syntaxa occurring away from the levees (compare Chapters VI.4 and VI.5). It further occurs in wetter climates, for example in Natal, and it is therefore quite possible that several ecotypes of this species also exist in South Africa.

On the outer edges of the levees, where the fine sandy alluvium is somewhat mixed with

TABLE VI.1.2 SALSOLA GLABRESCENS COMMUNITY

Relevé no.	169	18	63	561	559	560	Sociability
SL	30° 38'	30° 33'	30° 35'	30° 34'	29° 47'	29° 36'	
EL	26° 30'	25° 56'	25° 55'	29° 19'	24° 24'	24° 08'	
Total cover (%)	55	60	95	-	90	100	
Total no. of species	12	8	9	5	4	3	
Salsola glabrescens	2b	3	5	4	5	5	2-5
Lycium arenicolum	1	2a	+	2b	2a		2
Diospyros lycioides	+		2b	1		2a	1-2
Eragrostis lehmanniana	2a	2b	2b	+			2
Chrysocoma tenuifolia	+	+	+				1-2
Setaria verticillata					+	2a	2-3
Pentzia globosa		2a	3				1-2
Asparagus suaveolens		+	+				2

further occurring in relevé 169: *Osteospermum spinescens* (2b), *Aster muricatus* (2a), *Asparagus setaceus* (+), *Walafrida saxatilis* (+), *Convolvulus ulosepalus* (+), *Cyperus usitatus* (+), *Lessertia pauciflora* (r); relevé 18: *Tragus koelerioides* (+), *Enneapogon brachystachyus* (+); relevé 63: *Acacia karroo* (r), *Celtis africana* (r); releve 561: *Tetragonia arbuscula* (+); relevé 559: *Tribulus terrestris* (3).

the loamy residual of the surroundings of the riverbed, a semi-open to dense scrub community dominated by *Salsola glabrescens* often occurs. As can be seen from table VI.1.2 the species *Lycium arenicolum* and *Diospyros lycioides* subsp. *lycioides* of the Diospyrion lycioidis can also be abundant in this *Salsola glabrescens* Community, whereas species of the Pentzio-Chrysocomion intrude into this community as well.

TABLE VI.1.3 STIPAGROSTIS NAMAQUENSIS-ERAGROSTIS LEHMANNIANA COMMUNITY

Relevé no.	474	509
SL	29° 23'	29° 06'
EL	23° 55'	23° 42'
Total cover (%)	60	25
Total no. of species	4	10
Stipagrostis namaquensis	3.2	2b.2
Eragrostis lehmanniana	2b.2	1.2
Stipagrostis obtusa		1.2
Stipagrostis ciliata		+.2
Aristida congesta		+.2
Tragus berteronianus		+.2
Eragrostis porosa		+.2
Orthanthera jasminiflora		+.1
Hirpicium echinus		+.2
Chenopodium schradianum	+.2	
Pentzia calcarea	+.1	
Phaeoptilum spinosum		r

The *Salsola glabrescens* Community is two layered: a shrub layer up to 2 m tall, and a groundlayer up to 0,60 m high. In FOSBERG's classification this community belongs mostly to 1B1.8c, gray microphyllous evergreen scrub.

At various localities along the Upper Orange River, particularly where the alluvial soil deposits cover an area of over 100 m wide, the vegetation of the Diospyrion lycioidis and the *Salsola glabrescens* Community has been cleared and the land is under cultivation (compare Chapter II.7.).

In the vicinity of Douglas sand accumulations of considerable extent, probably of mixed alluvial and aeolian origin occur (compare Chapter II.5.). On deep sandy semi-stabalized dunes in that area a *Stipagrostis namaquensis* - *Eragrostis lehmanniana* Community occurs, which physiognomically strongly resembles the Stipagrostietum amabilis LEISTNER et WERGER 1973 of the dune crests of the southern Kalahari. This is largely due to the strong physiognomic resemblences between *Stipagrostis namaquensis* and *Stipagrostis amabilis*. Also in floristic composition the two commonities show similarities as can be seen from table VI.1.3 and table 2 in LEISTNER & WERGER (1973).

TABLE VI.1.4 ERAGROSTIS LEHMANNIANA-ASTHENATHERUM GLAUCUM COMMUNITY

Relevé no.	504
SL	29° 06'
EL	23° 38'
Total cover (%)	20
Total no. of species	10
Eragrostis lehmanniana	2a.2
Asthenatherum glaucum	+.2
Stipagrostis obtusa	2a.2
Stipagrostis ciliata	+.2
Eragrostis brizantha	+.2
Helichrysum arenicola	+.2
Orthanthera jasminiflora	+.1
Tribulus zeyheri	+.2
Limeum fenestratum	+.1
Celosia linearis	+.2

The grass tussocks can be up to 1,80 m tall and the community belongs physiognomically to FOSBERG's category 2G2.1, seasonal grass steppe.

In the same area an extensive flat plain of alluvial-aeolian sand occurs on which an *Eragrostis lehmanniana-Asthenatherum glaucum* Community is found which is floristically closely related to the Hirpicio echini - Asthenatheretum LEISTNER et WERGER 1973 of the dune valleys of the southern Kalahari. Relevé 504 (table VI.1.4) is an example of this community. This community consists of a single grass layer of up to 0,35 m high and belongs to FOSBERG's formation 3C2.1, seasonal desert grass; the dense phases belong to 2G2.1, seasonal grass steppe.

VI.2 THE GRASSLAND COMMUNITIES OF THE EASTERN UPPER ORANGE RIVER VALLEY

The entire eastern half of the South African plateau, making up a large part of the Eastern Cape and the Orange Free State, is dominated by grassland vegetation. Although the precipitation in this area is such that according to WALTER (1962) woody vegetation would be expected regularly occurring frosts might be the cause of the complete absence of trees and large shrubs in all but sheltered sites. ACOCKS (1953) states that these regions "are too dry and/or too frosty for the development of any kind of forest. Only on rocky hills, which are rare on the plains, and on the mountains, will a few scattered shrubs be found". Another factor of significant importance preventing the development of woody vegetation in these areas, is fire (DAUBENMIRE, 1968b). Fire certainly has to be regarded as a natural factor in the grassland areas of southern Africa, since numerous fires are reported to have been started by lightning and also by sparks generated when boulders rolling downhill collide (BAYER, 1955; PIENAAR, 1956; KILLICK, 1963; WALTER, 1968; SCOTT, 1970). Hence, the question remains as yet unanswered as to whether the eastern plateau grassland areas constitute a zonal vegetation or whether it is entirely a pyrophilic vegetation (WALTER, 1968).

As mentioned in Chapter II.6, two Veld Types cover the grasslands of the Upper Orange River valley: the southern variation of the sandy *Cymbopogon-Themeda* Veld (Veld Type 49) fringing the borders of Lesotho, and the southern variation of the dry *Cymbopogon-Themeda* Veld (Veld Type 50) in a narrow zonebetween the former Veld Type and the False Upper Karoo (ACOCKS, 1953). A general account of the eastern grasslands is given by BEWS (1918) in Clementsian terms.

Grasslands with *Themeda triandra* occur over extensive areas in Africa. LEBRUN (1947) provisionally described the East African grasslands, in which *Themeda triandra* is dominant or frequent, under the name Themedetalia triandrae. The character species for this order, as listed by him and by TATON (1948), do not occur in the grassland communities of the South African Highveld, however, and it is thus likely that these communities do not belong to the same order as the East African ones. VOLK & LEIPPERT (1971), discussing a *Themeda* community from South West Africa, used the class name Themedetea, which is a nomen nudum, since they do not indicate which syntaxa are meant to be incorporated in this class.

The exact syntaxonomical position of the grasslands in the eastern part of the Upper Orange River catchment area cannot be established at present.

In the present study only 24 relevés were sampled in the grassland vegetation. As shown by table VI.2 three communities and two subcommunities could clearly be distinguished. However, for two reasons no attempt has been made to classify these communities into a formal phytosociological system. Firstly, the grassland area covered in this study represents only a very small fraction of the entire eastern-plateau grasslands, which are closely related floristically (fig. VI.2). Thus, only a small fraction of the floristic variation in these grasslands was sampled and a phytosociological classification based on such a limited sample cannot be expected to be scientifically accurate. Secondly, comprehensive plant ecological studies have been undertaken in recent years in various parts of this grassland region, the results of which are being worked on at present (SCHEEPERS, in prep.; MORRIS, in prep.; JARMAN, in prep.). These studies can be expected to result in scientifically more reliable and more applicable classifications, into which the results provided here can be incorporated.

The *Brachiaria serrata - Elyonurus argenteus* Community occurs on sites, which are not too severely overgrazed and trampled, mainly in the area covered by the sandy *Cymbopogon-Themeda* Veld (ACOCKS, 1953). The community is usually found on somewhat deeper pseudopodzolic soils, over 0,50 m deep, with a slightly acid top soil of loamy sand, on nearly horizontal layers of Molteno sandstones (compare Chapter II.5). Sometimes it was also encountered on shallow lithosols on south facing slopes of 8° to 17° (relevés 239, 251). Species positively differentiating this community from the two others are the grasses *Brachiaria serrata, Elyonurus argenteus, Hyparrhenia hirta, Eragrostis racemosa, Cymbopogon excavatus* and *Helictotrichon longifolium* and the forbs *Anthospermum rigidum, Helichrysum niveum, Dianthus basuticus* subsp. *basuticus, Helichrysum caespititium , Ajuga ophrydis, Dicoma anomala, Helichrysum rugulosum, Haplocarpha scaposa, Euphorbia striata* and *Senecio erubescens*. Other species of importance in this community are the grasses *Aristida diffusa* var. *burkei, Eragrostis curvula, Heteropogon contortus* and *Cymbopogon plurinodis* (table VI.2). The average number of species in this community amounts to 25.

Apart from the vegetation in relevé 257, this community consists of virtually one layer of grasses and forbs, up to 0,60 m in height, with a cover of 75 per cent on the average. Prostrate, trailing and very low plants are so rare that they do not constitute a separate vegetation layer. In relevé 257 the shrub *Euryops annae* is codominant. This shrub is avoided by sheep and shows a vigorous growth after heavy overgrazing of the field. It is evergreen and can be up to 2 m tall. In FOSBERG's (1967) structural classification the *Brachiaria serrata - Elyonurus argenteus* Community belongs to formation 1M2.1, seasonal orthophyll short grass, except for the vegetation of relevé 257, which belongs to formation 1B1.7, straight evergreen narrow sclerophyll scrub, or formation 1C1.2(b), microphyllous evergreen dwarf scrub.

Some of the association analysis end groups of ROBERTS' study of Thaba 'Nchu (1966), particularly end group 4, show strong floristic affinities with the *Brachiaria serrata - Elyonurus argenteus* Community, and it is possible that the same community occurs in the Upper Orange River valley and at Thaba 'Nchu.

On damp sites with a deep soil of loamy sand, usually in slight depressions on gentle slopes or plains (delle) of Molteno sandstones, upstream of Aliwal North, the *Eragrostis plana - Eragrostis gummiflua* Community occurs (fig. VI.2). Cattle and sheep often concentrate on such places, with the result that these sites are heavily trampled. The community can be divided into two subcommunities: the *Eragrostis plana - Themeda triandra* Subcommunity on the most loamy sites, which are not too heavily trampled, and the *Eragrostis plana - Eragrostis lehmanniana* Subcommunity on the sandier and more heavily trampled bottomlands. The *Eragrostis plana - Eragrostis gummiflua* Community is floristically positively differentiated from the other grassland communities by *Eragrostis plana* and *Walafrida densiflora*. *Eragrostis plana* is very abundant in this community. Other species of importance are *Eragrostis curvula* and *Cymbopogon plurinodis*.

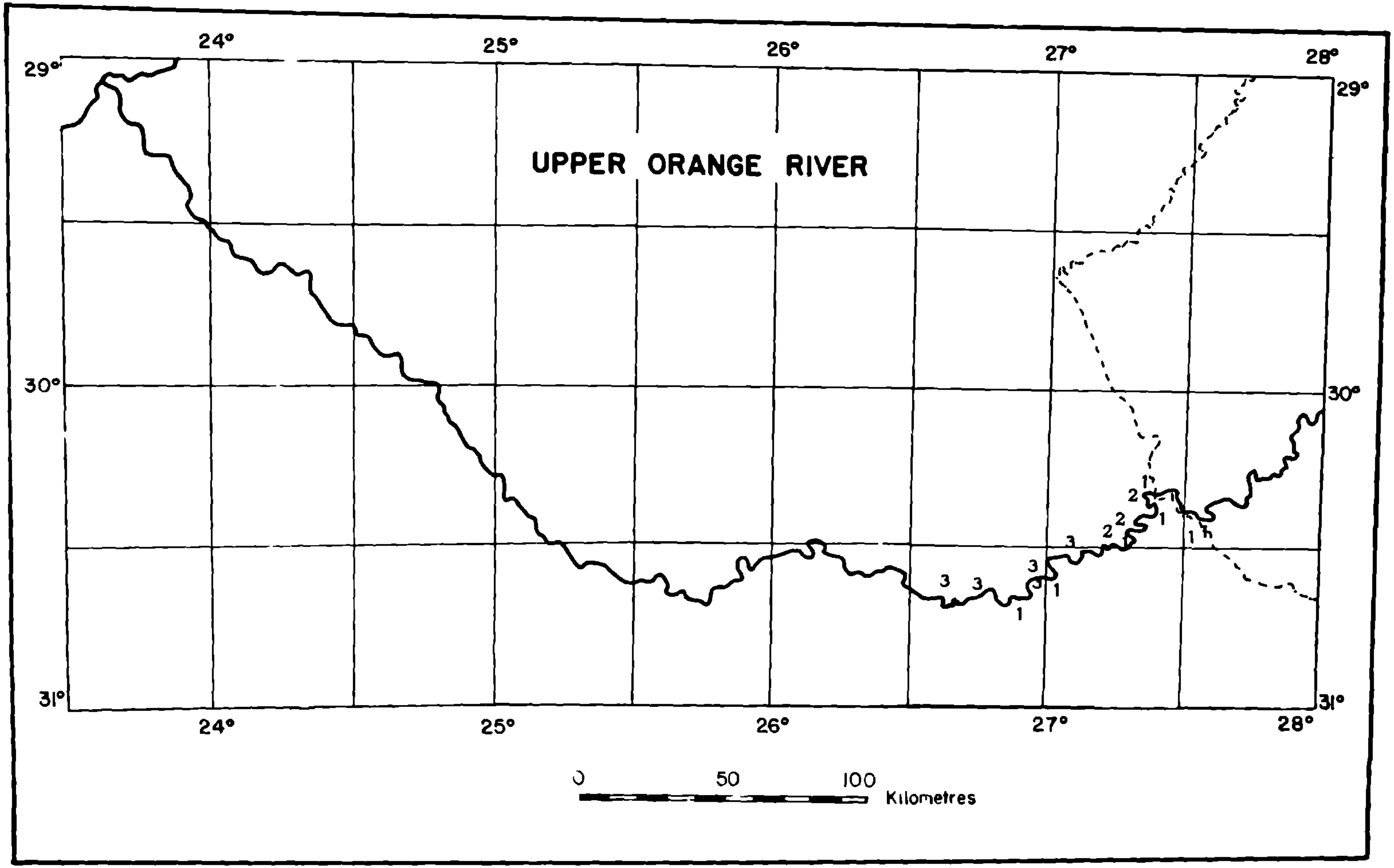


Fig. VI.2 Distribution of eastern grassland communities in the study area. 1. *Brachiaria serrata-Elyonurus argenteus* Community; 2. *Eragrostis plana-Eragrostis gummiflua* Community; 3. *Pentzia globosa-Eragrostis curvula* Community.

The two subcommunities differ floristically from one another in that *Themeda triandra* and *Panicum stapfianum* occur in the *Eragrostis plana - Themeda triandra* Subcommunity, but are lacking in the *Eragrostis plana - Eragrostis lehmanniana* Subcommunity. In the latter subcommunity *Eragrostis gummiflua, Pentzia globosa, Cyperus usitatus, Helichrysum dregeanum, Aristida congesta, Euryops annae* and *Eragrostis lehmanniana* occur, whereas all of these species are absent from the *Eragrostis plana - Themeda triandra* Subcommunity (table VI.2). The average number of species of the *Eragrostis plana - Eragrostis gummiflua* Community is 18 to 19.

Except for relevé 244, where *Euryops annae* is important, the structure of the *Eragrostis plana - Eragrostis gummiflua* Community is similar to that of the *Brachiaria serrata - Elyonurus argenteus* Community. In the *Eragrostis plana - Themeda triandra* Subcommunity the average total cover is much higher however, with values of 95 to 100 per cent. In the *Eragrostis plana - Eragrostis lehmanniana* Subcommunity total cover values average 65 per cent. In FOSBERG's (1967) classification these subcommunities both belong to formation 1M2.1, seasonal orthophyll short grass. The vegetation of relevé 244 belongs to formation 1C1.2(b), microphyllous evergreen dwarf scrub.

In the vicinity of Aliwal North, where the False Upper Karoo merges into the grassland vegetation, another grassland community occurs, the *Pentzia globosa - Eragrostis curvula* Community (fig. VI.2). It is found on slightly acid loamy sands and sandy loams, over 0,25 m deep, on level to slightly sloping Molteno and Beaufort sandstones. These sites have all been moderately to severely overgrazed, and erosion, particularly sheet erosion, is common. The following species, of which many are Pentzio-Chrysocomion species (comp. Chapter VI.3), differentiate positively between this community and the other grassland communities: the dwarf shrubs *Pentzia globosa, Chrysocoma tenuifolia, Aster muricatus* and *Pterothrix spinescens*, the grasses *Eragrostis obtusa, Tragus koelerioides* and *Sporobolus fimbriatus*, the forbs *Hermannia coccocarpa, Listia heterophylla* and *Solanum supinum* and the sedge *Kyllinga alba*. Other important species in this community are *Eragrostis curvula, Themeda triandra, Aristida congesta, Digitaria eriantha* and *Euryops annae*. The latter species again indicates the severity of overgrazing in this community. The floristic composition of the *Pentzia globosa - Eragrostis curvula* Community, as compared with the two other grassland communities discussed, shows clearly that the former occurs in a drier environment than the other two. Species indicating this are particularly the Pentzio - Chrysocomion species such as *Pentzia globosa, Chrysocoma tenuifolia, Eragrostis obtusa, Tragus koelerioides, Aristida congesta* and others (table VI.2). The average number of species of the *Pentzia globosa - Eragrostis curvula* Community is 21.

The *Pentzia globosa - Eragrostis curvula* Community can consist of three layers. The most heavily overgrazed patches have a shrub layer of *Euryops annae*, between 1 and 2 m tall, covering 20 to 25 per cent. There is always a dwarf shrub and grass layer, in which grasses are usually dominant, up to 0,70 m in height, and covering between 20 and 50 per cent in the phases with *Euryops annae*, but up to 95 per cent in the other stands. Sometimes there is a groundlayer of plants up to 0,05 m high, whose cover can reach a value of up to 15 per cent. In FOSBERG's (1967) classification, the *Pentzia globosa - Eragrostis* *curvula* Community usually belongs to formation 1H1.3, open evergreen microphyllous dwarf scrub, when *Euryops annae* is not abundant. The phases where *Euryops annae* dominates belong to formation 1B1.7, straight evergreen narrow sclerophyll scrub, or when low, 1C1.2(b), microphyllous evergreen dwarf scrub.

The communities discussed under the name "*Themeda*-veld" by MOSTERT (1958) show a considerable degree of similarity with the *Pentzia globosa - Eragrostis curvula* Community, but the phases with *Euryops annae* do not occur in MOSTERT's study area north of Bloemfontein.

Gazania krebsiana, Aristida diffusa var. *burkei* and *Convolvulus boedeckerianus* are common to the *Brachiaria serrata - Elyonurus argenteus* Community and the *Pentzia globosa - Eragrostis curvula* Community, whereas they are virtually absent from the *Eragrostis plana - Eragrostis gummiflua* Community. Common to the latter and the *Pentzia globosa - Eragrostis curvula* Community and absent from the *Brachiaria serrata - Elyonurus argenteus* Community are *Cyperus usitatus* and *Sporobolus fimbriatus,* whereas *Eragrostis capensis* is common to the *Brachiaria serrata - Elyonurus argenteus* and the *Eragrostis plana - Eragrostis gummiflua* Communities, but virtually absent from the *Pentzia globosa - Eragrostis curvula* Community.

Of the species common to all three communities *Eragrostis curvula, Themeda triandra, Helichrysum dregeanum, Aristida congesta, Heteropogon contortus, Cymbopogon plurinodis, Walafrida saxatilis, Hermannia depressa, Sutera aurantiaca* and *Setaria flabellata* are the most constant (table VI.2).

In a rigid analysis of species/habitat associations, ROBERTS (1971) investigated habitat preferences for a number of grass species occurring in the grassland communities described above. Data were collected at Thaba 'Nchu. From the results some indication on the autecology of certain species might be obtained, although, due to the rigid and arbitrary definition of the habitat categories, the results should be interpreted carefully. ROBERTS (1971) found, for example, a positive association between slope angle of 0^o to 5^o and a low degree of stoniness and the occurrence of *Eragrostis plana,* and between sloping sites with angles from 6^o to 30^o and the occurrence of *Brachiaria serrata.* The latter species was also found to be associated with stoniness of the soil, a low degree of erosion and trampling and a sandy soil. *Tragus koelerioides* was found to be associated with, amongst others, a medium degree of erosion and a high degree of trampling. These and some more results of ROBERTS (1971) fit reasonably well with the above outline of the habitats on which the grassland communities in the Upper Orange River valley occur.

VI.3 THE COMMUNITIES OF THE PLAINS OF THE FALSE UPPER KAROO (PENTZIO-CHRYSOCOMION prov.)

The pediplains between the mesas, kopjes and ridges in the wide stretch of land from Aliwal North to Petrusville, bear a largely uniform vegetation of dwarf shrub steppe. Soils are sandy loams, usually more than 1 m deep and of the solonetzic type, particularly in the area east of Colesberg. The top soil is slightly acid, becoming alkaline in the B horizon (compare Chapter II.5). Sheet and gully erosion occur on a large scale.

The slope angle of the pediplains is usually between 0° and 3° and seldomly measures up to 7° (cf. FAIR, 1948). The underlying substrate is formed by Beaufort sandstones, mudstones and rarely by shales.

As discussed in Chapter II.6 this vegetation is a result of anthropogenic influences, particularly of overgrazing by sheep and other forms of agricultural mismanagement. Therefore, the vegetation is floristically relatively poor and character species are not very constant. Hence, phytosociological characterization is more difficult than in the case of vegetation types, that are not so poor in species due to anthropogenic influences.

Nearly the entire vegetation of the plains in this area is constituted by one association, the Hermannio coccocarpae-Nestleretum confertae ass. nov., with the following character and differential species: *Hermannia coccocarpa, Osteospermum scariosum, Convolvulus boedeckerianus, Lessertia pauciflora* (d), *Nestlera conferta, Schizoglossum capense* and *Cynodon hirsutus*. With the exception of *Nestlera conferta,* these species are inconspicuous and never dominant. *Nestlera conferta* is usually a bright green, compact, prostrate dwarf shrub. The association is subdivided into three subassociations (table VI.3).

On the somewhat sandier sites, often fringing the pediment slopes, where sheet erosion is a common phenomenon, the subassociation aptosimetosum marlothii subass. nov. occurs. Differential for this subassociation are the dwarf shrubs *Aptosimum marlothii* and *Eriocephalus spinescens* and the grass *Enneapogon brachystachyus*. ACOCKS (1953) lists *Aptosimum marlothii* as an Arid Karoo species intruding the False Upper Karoo. The average number of species of the aptosimetosum marlothii is 14. The subassociation is encountered mainly in the area between Colesberg and Petrusville, possibly because the soil is more often sandier in this area as a result of a slight influence of Kalahari sand deposition, that finds its southeastern-most extension there (fig. VI.3).

Between Aliwal North and Colesberg, particularly between Aliwal North and Bethulie, the subassociation eragrostietosum curvulae subass. nov. is found frequently (fig. VI.3). It is typified by the differential species *Eragrostis curvula, Cyperus usitatus, Themeda triandra, Helichrysum dregeanum* and *Solanum supinum.* The dwarf shrub *Pentzia globosa* reaches constantly high cover-abundance values in this subassociation, whereas *Gazania krebsiana* occurs only infrequently. This subassociation seems to be the most typical form of the association, because *Eragrostis curvula* and *Themeda triandra,* which are regarded as relict species of the former grassland vegetation, are among the differential species of the subassociation, and because this subassociation covers the largest area by far. *Eragrostis curvula* and *Themeda triandra* appear to establish themselves easily from seed, and are most abundant on sites that are not so heavily overgrazed and trampled, or that have been withdrawn from grazing for some time. Except for *Cyperus usitatus,* the differential species of the eragrostietosum curvulae are all common in the Rhoetea erosae communities (compare Chapter VI.4). The average number of species of this subassociation is 16.

On sites on the plains east of Colesberg that are quite strongly eroded and where the remaining top soil is a very hard, compact loam, a third community occurs, the

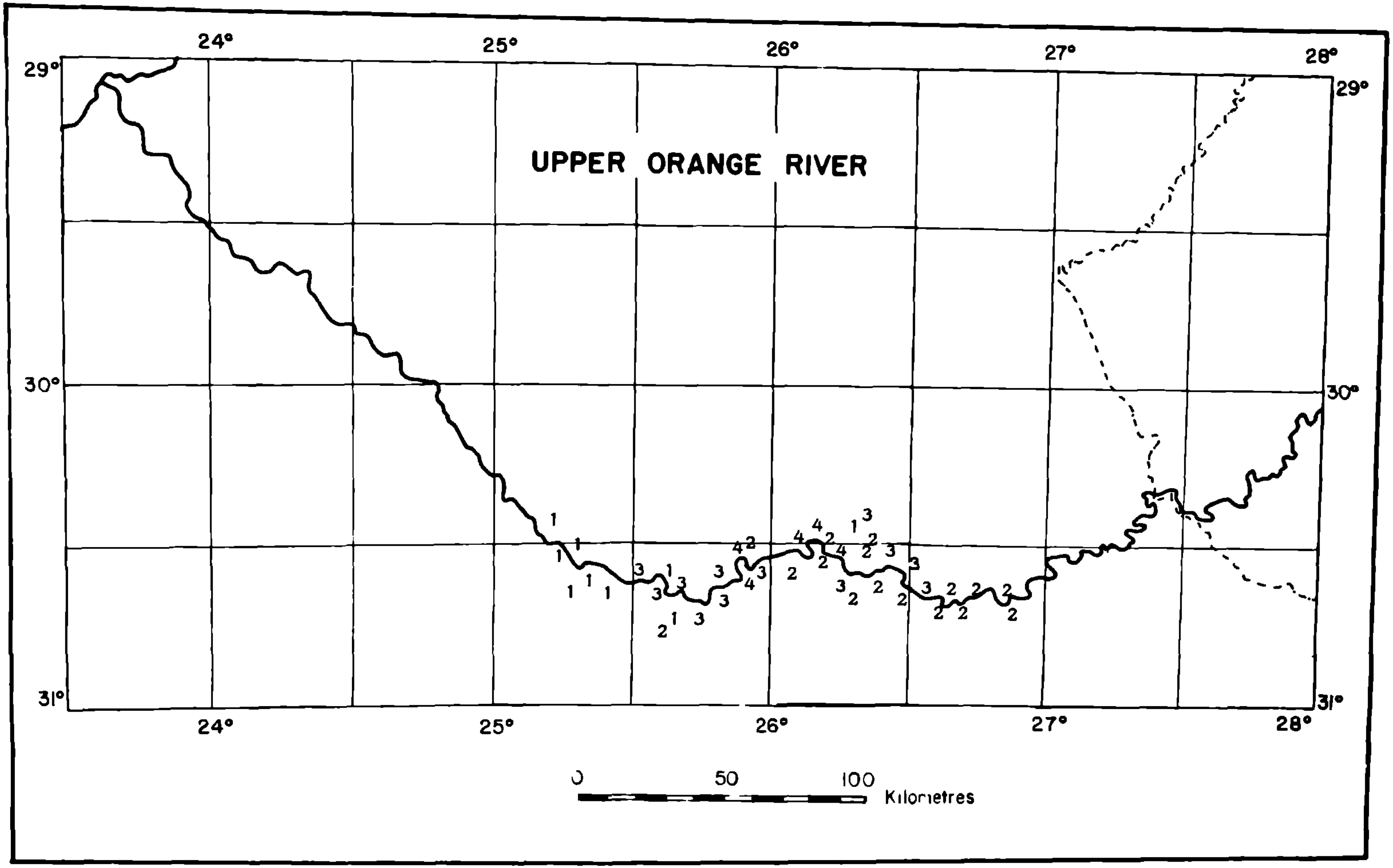


Fig. VI.3 Distribution of Hermannio coccocarpae-Nestleretum confertae in the study area. 1. aptosimetosum marlothii; 2. eragrostietosum curvulae; 3. oropetietosum; 4. *Eragrostis lehmanniana*-variant.

oropetietosum subass. nov., with the diminutive grass *Oropetium capense* as differential species (fig. VI.3). This species is one of the few grasses reported to withstand extreme desiccation (GAFF, 1971). *Oropetium capense* was also found to be typical of some of the more compact soils in the southern Kalahari (LEISTNER & WERGER, 1973). The average number of species of the oropetietosum is 13.

A variant with *Eragrostis lehmanniana* of the Hermannio coccocarpae-Nestleretum confertae, which cannot be placed unequivocally into one of the subassociations, also occurs in the Upper Orange River area (fig. VI.3). It is found on sites that have been ploughed several years ago and have since been left unused, and on the most severely eroded places, that have been withdrawn from grazing for a number of years and are recovering. This variant is usually very poor in species with only 9 on the average, and *Eragrostis lehmanniana* scores constantly high cover values.

It is probable that in the same region, but outside the study area floristically related communities occur, and possibly some of the minor communities described in Chapter VI.7 are related to the Hermannio coccocarpae-Nestleretum confertae. Although no complete syntaxonomic hierarchy can be described at present, it is likely that the Hermannio coccocarpae-Nestleretum confertae together with some related communities, constitute an alliance, the Pentzio-Chrysocomion (prov.). This alliance would probably stand on its own and its character species would at the same time be the character species for the order, Pentzio-Chrysocometalia (prov.), and the class, Pentzio-Chrysocometea (prov.). These species would be the wide-spread "Karoo pioneers", which have their optimal presence or cover-abundance in the Pentzio-Chrysocomion communities. They are the dwarf shrubs *Chrysocoma tenuifolia*, *Pentzia globosa*, *Walafrida saxatilis*, *Lycium salinicolum* (which can also occur as a low shrub), *Gnidia polycephala*, *Aster muricatus*, *Pterothrix spinescens* and *Hermannia linearifolia*, the grasses *Tragus koelerioides*, *Eragrostis lehmanniana*, *Aristida congesta* and *Eragrostis obtusa*, the prostrate forb *Indigofera alternans* and the low rosette plants *Gazania krebsiana* and *Mariscus capensis*. In the text and in the tables they are listed as Pentzio-Chrysocomion species.

Most of the dwarf shrubs are gray or brownish microphyllous "evergreens", giving the Karoo vegetation its marked "dead" appearance. They can withstand long periods of droughts, owing to their low transpiration, the high osmotic pressure of their cell sap, and their small leaf surfaces (HENRICI, 1940; WALTER, 1962). The osmotic pressure is highest, when the soil moisture content is lowest (compare also AALTONEN, 1923). It was shown by ROUX (1966), that rains falling late in the growing season invigorate the growth of dwarf shrubs, contrary to the rains falling early in the growing season and which stimulate the grass growth in this vegetation. A number of species of the Rhoetea erosae communities occur as accompanying species in the Hermannio coccocarpae-Nestleretum confertae. Most frequent of these are *Aristida diffusa* var. *burkei*, *Nenax microphylla*, *Limeum aethiopicum*, *Aptosimum depressum*, *Hibiscus marlothianus*, *Trichodiadema pomeridianum* and *Hibiscus pusillus*. In his account of the plant communities of Tussen die Riviere Game Farm, O.F.S., WERGER (1973a) gave a preliminary description, based on a small amount of samples, of the Hermannio coccocarpae-Nestleretum confertae, under the provisional name *Chrysocoma tenuifolia* - *Lessertia pauciflora* Community. The association was not yet subdivided into subassociations. The variant with *Eragrostis lehmanniana* of the Hermannio coccocarpae-Nestleretum confertae was described as the *Eragrostis lehmanniana - Chrysocoma tenuifolia* Community in the above-mentioned paper.

All the subassociations and the variant of the Hermannio coccocarpae-Nestleretum confertae are generally two-layered: a dwarf shrub and grass layer of 0,35 to 0,50 m high, and a groundlayer of very short plants, up to 0,08 m high. In the aptosimetosum marlothii the uppermost layer covers between 10 and 25 per cent on the average, and in exceptional cases up to 50 per cent, whereas the groundlayer rarely covers more than 10 per cent. In the eragrostietosum curvulae the layer of dwarf shrubs and grasses covers between 35 and 70 per cent, and the groundlayer usually 5 per cent, but occasionally up to 20 per cent of the surface. In the oropetietosum the percentages of cover of both layers vary widely. The range in cover values of the uppermost layer is from 15 to 80 per cent, and that of the groundlayer from 5 to 30 per cent. The variant with *Eragrostis lehmanniana* always scores high cover values of between 50 and 70 per cent for the uppermost layer, but the groundlayer rarely covers more than 5 per cent.

In FOSBERG's physiognomic classification (1967) the denser phases of all the subassociation and the variant belong to formation 2C1.3, evergreen narrow sclerophyll dwarf steppe scrub. The more open phases, occurring mainly in the aptosimetosum marlothii and the oropetietosum, belong to formation 2F1.2, evergreen narrow sclerophyll dwarf shrub steppe savanna.

VI.4 THE SHRUB COMMUNITIES OF THE EASTERN GRASSLAND AREA AND THE FALSE UPPER KAROO (RHOETEA EROSAE)

VI.4.1 Introduction

In this chapter the multistratal shrubby communities occurring on the sloping terrain in the eastern grassland area, the sandy and dry *Cymbopogon - Themeda* Veld (ACOCKS, 1953, Veld Types 48 and 50), and in the False Upper Karoo (ACOCKS, 1953, Veld Type 36) are discussed. These communities have strong floristic similarities and belong to the class Rhoetea erosae. The floristic similarities shown by these hillside communities of the above named three Veld Types are perhaps a strong argument for the thesis, that the False Upper Karoo, before the colonization by white sheep farmers just over a century ago, also was a *Cymbopogon - Themeda* grassland (compare Chapter II.6).

The following syntaxa are discussed in this chapter (the code in front of the syntaxa names symbolizes the relationships between the syntaxa):

I	Rhoetea erosae
IA	Grewio-Rhoetalia erosae
IA1	Indigofero spinescentis-Rhoion erosae
IA1a	Rhamno-Rhoetum
IA1b	Rhoo-Aloetum ferocis
IA2a	Blepharido-Rhoetum

IB	Rhoetalia ciliato- erosae
IB1	Hibisco marlothiani-Rhoion erosae
IB1a	Osteospermetum leptolobi
(1)	typicum
(2)	aptosimetosum marlothii
IB1b	Stachyo-Rhoetum
(1)	polygaletosum
(2)	hermannietosum candidissimae
(2a)	*Salvia namaensis*-variant
IB1c	Nanantho vittati-Rhoetum
IB2a	Mayteno polyacanthae-Oleetum africanae
(1)	typicum
(2)	chamareetosum
IB3a	Setario lindenbergianae-Buddleietum salignae

VI.4.2 The shrub communities of mesic sites (Grewio-Rhoetalia erosae)

The area between Aliwal North and the South African-Lesotho border is characterized by relatively strong relief (figs. II.2 and II.6). The Orange River has cut a deep through mainly through hard Molteno sandstones and the countryside further away from the riverbed is also relatively strongly dissected. The soils on the hill- and mountainsides in this area are mainly shallow, neutral to slightly acid lithosols. Within the boundaries of South Africa this part of the Upper Orange River valley receives the most precipitation, while the lowest temperatures are recorded. The climate may be typified as subhumid warm temperate (compare Chapter II.2.8). On the plains and on some slopes in this area grassland communities occur, which have been discussed in Chapter VI.2. On the steeper slopes, however, shrubby communities occur, which are generally rich in species.

The Rhamno-Rhoetum ass. nov. occurs on steep Molteno sandstone slopes of nearly always over 15° with a southerly aspect and mainly south or south-east facing. Relevés 241 and 267 (table VI.4) were recorded on northerly facing slopes, but were situated such that they were protected by surrounding mountains from influences usually associated with northerly facing sites. The Rhamno-Rhoetum is characterized by a large number of character species and by differential species against the other associations of the Grewio-Rhoetalia erosae and against several other associations of the Rhoetea erosae. Shrub and small trees amongst these species are *Myrsine africana, Rhamnus prinoides, Asparagus denudatus, Rhus dentata, Rhus divaricata, Halleria lucida, Cliffortia linearifolia* (d), *Cussonia paniculata,* the climber *Clematis brachiata* (d), *Tarchonanthus camphoratus* (d), *Kiggelaria africana* and *Heteromorpha arborescens*. Grasses are *Helictotrichon longifolium, Pentaschistis setifolia* (d), *Koeleria cristata* (d), *Cymbopogon validus, Harpochloa falx* (d) and *Festuca scabra* (d), and further character and differential species, occurring in the lowest layers are *Helichrysum odoratissimum, Helichrysum rudifolium* (d), *Vernonia capensis, Hypericum aethiopicum, Carex spicato-paniculata, Crassula filamentosa, Crassula harveyi, Haplocarpha scaposa* (d), *Senecio latifolius, Stachys aethiopica, Schoenoxiphium sparteum, Delosperma concavum, Scabiosa columbaria* (d), *Lactuca capensis* (d), *Artemisia afra* (d), *Dimorphotheca cuneata, Pellaea quadri-*

pinnata and *Satureia biflora*. Some other species also often score high cover-abundance values in this association. They are the shrubs and trees *Aster filifolius*, which is often regarded as an indicator of overgrazing, *Osyris lanceolata*, *Clutia pulchella*, *Rhus erosa*, *Rhus undulata* var. *burchellii*, *Diospyros lycioides* subsp. *lycioides*, *Diospyros austro-africana*, *Olea africana* and a few others (table VI.4). The average number of species of the Rhamno-Rhoetum is 54.

As the above list of species and table VI.4 show, the Afro-montane element is well represented in this association. Several of the species encountered in this association or their closest allies are found in the montane zone throughout eastern Africa and also occur scattered in temperate Europe and Asia, particularly in the Himalayas (compare Chapter III; HEDBERG, 1965; CHAPMAN & WHITE, 1971).

The association usually occurs as a rather dense scrub. Total aerial cover of the stands of the association is usually between 65 and 70 per cent. Layers are not always clearly distinct from one another, but often it is possible to separate a shrub and small tree layer, 1 to 3,5 m in height although sometimes up to 5 m tall, and covering between 40 and 50 per cent on the average, from a groundlayer that is up to 0,70 m and sometimes up to 1 m high, usually covering between 20 and 30 per cent. In FOSBERG's (1967) physiognomic classification system the Rhamno-Rhoetum cannot be determined easily, since about half of the dominant woody species are evergreen and the remainder half deciduous. The association is possibly best classified as intermediate between formations 1B1.4(a), mesophyllous evergreen broad sclerophyll scrub, and 1B2.1(a), mesophyllous deciduous orthophyll scrub, for the dense phases, and between 2B1.2, evergreen broad sclerophyll steppe scrub, and 2B2.1, deciduous orthophyll steppe scrub, for the slightly more open phases. Relevés 268, 270 and particularly 269 and 267, sampled in the Herschel District, were very heavily overgrazed and trampled by goats and do not represent typical examples of this association, neither in floristics nor in structure. Relevés 206, 556, 536 are floristically atypical. They represent isolated phytocoenoses situated considerably further westwards in the drier False Upper Karoo, away from the main distribution area of the association.

In an association analysis of the vegetation of Thaba 'Nchu, a flat-topped mountain approximately 80 km east of Bloemfontein, ROBERTS (1966) arrived at 28 end groups of the dichotomy, which he called communities. Data for the association analysis were collected systematically, using 4 x 4 m samples in bush. Only presence or absence data were used in the computation. The results of such a study are difficult to correlate with those of a floristic analysis of the present type. From ROBERTS' short descriptions of his rigidly determined "communities" it is apparent,however, that some of the end groups are probably identical with the presently described Rhamno-Rhoetum. Particularly his end groups 14 (*Euclea-Aster filifolius* Scrub) and 15 (*Euclea-Clutia* Bush) likely belong to the Rhamno-Rhoetum. It is interesting in this context that ROBERTS found a highly significant positive association between end group 14 and slopes of Molteno sandstones. The correlation between the Rhamno-Rhoetum and ROBERTS' end group 14 and Molteno sandstone is possibly more a matter of the occurrence thereof at high altitudes. It is here, as a result of stratigraphy, where Molteno sandstone emerges.

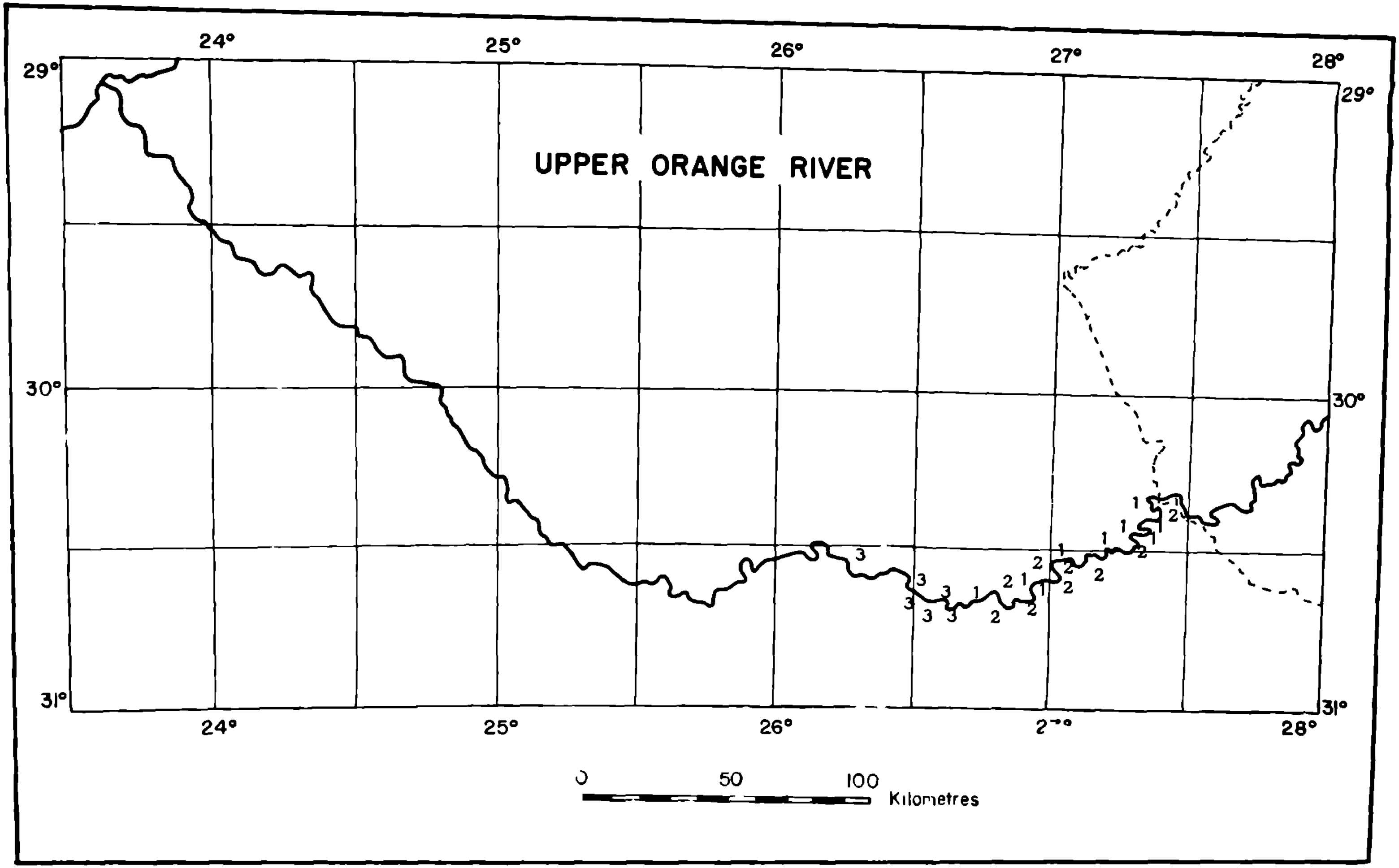


Fig. VI.4 Distribution of Grewio-Rhoetalia erosae in the study area. 1. Rhamno-Rhoetu Rhoo-Aloetum ferocis; 3. Blepharido-Rhoetum.

In the same area where the Rhamno-Rhoetum occurs, the Rhoo-Aloetum ferocis ass. nov. is found (fig. VI.4). The latter occurs mainly on Molteno sandstones, but occasionally on Red Beds, Beaufort and doleritic substrates too. It is encountered on neutral to slightly acid lithosols on steep slopes, but in contrast with the habitat of the Rhamno-Rhoetum, these slopes where the Rhoo-Aloetum ferocis occurs are facing northerly. The Rhoo-Aloetum ferocis is a shrubby community that is characterized by the following character species and differential species as against the other Grewio-Rhoetalia erosae communities: the liliaceous succulent,tree-like *Aloe ferox*, the shrubs *Asparagus virgatus*, *Hermannia cuneifolia* var. *glabrescens* (d) and *Ehretia rigida* (d), the climber *Antizoma angustifolia* and the groundlayer species *Rhynchelytrum repens* (d), *Pavonia burchellii*, *Aristida bipartita*, *Crassula cooperi*, *Crassula transvaalensis*, *Brachystelma* spec. and *Cotyledon orbiculata-decussata* complex (d). As in the Rhamno-Rhoetum, woody species such as *Aster filifolius*, *Osyris lanceolata*, *Clutia pulchella*, *Rhus erosa*, *Rhus undulata* var. *burchellii*, *Diospyros lycioides* subsp. *lycioides*, *Diospyros austro-africana*, *Olea africana* and a few others can be important. The shrub *Indigofera spinescens* is also often abundant (table VI.4). The average total number of species of the association is 41.

Aloe ferox finds its furthest land-inward distribution in this area and serves as a constant character species. The considerable number of succulents amongst the character and differential species of the Rhoo-Aloetum ferocis suggest that the northerly slopes, which are typical for the association, involve a much hotter and drier habitat than the mesic southerly slopes, on which the Rhamno-Rhoetum occurs. Also species like *Eustachys paspaloides*, *Enneapogon scoparius*, *Asparagus suaveolens*, *Lantana rugosa* and several others, which are commonly found in the drier False Upper Karoo area and which positively differentiate between the Rhoo-Aloetum ferocis and the Blepharido-Rhoetum on the one hand and the Rhamno-Rhoetum on the other, illustrate this point.

The Rhoo-Aloetum ferocis is an open shrub community. The shrub layer with *Aloe ferox* included, covers usually between 25 and 45 per cent, and is commonly between 1 and 4 m high. Occasionally a very open tree layer of *Olea africana*, 6 to 7 m high, occurs. The cover of the groundlayer which is up to 0,75 m high, varies considerably. Total aerial cover of the vegetation is 55 per cent on the average, but varies between 35 and 75 per cent. In FOSBERG's (1967) system the Rhoo-Aloetum ferocis belongs to formation 2B1.2, evergreen broad sclerophyll steppe scrub.

Some of the relevés taken in the Herschel District are structurally not typical, since they have been overgrazed heavily by goats, and the woody elements in the vegetation are often felled to a considerable extent by the local native population for fuel. Relevé 265 is further floristically atypical, because it is situated on a less steep slope. Relevés 218 and 219 are floristically slightly different from the other stands of the association, probably owing to their situation on a south-easterly facing slope, at the opening of the narrow valley trough of the Orange River, towards the more open country near Aliwal North. Relevé 245 is clearly transitional between the Rhamno-Rhoetum and the Rhoo-Aloetum ferocis.

The Rhamno-Rhoetum and the Rhoo-Aloetum ferocis have a number of species in common, which are absent from all other communities of the Rhoetea erosae. They are accordingly combined into the alliance Indigofero spinescentis-Rhoion erosae all. nov., which has the following character and differential species: the shrubs *Indigofera spinescens*, *Aster filifolius* (d), *Osyris lanceolata* (d) which also occurs in the Setario lindenbergianae-Buddleietum salignae (see below), *Clutia pulchella*, *Asparagus laricinus* (d), *Euryops annae* (d) and *Ochna atropurpurea*, the grasses *Brachiaria serrata* (d), *Setaria flabellata* (d), *Eragrostis racemosa* (d) and *Eragrostis capensis* (d), and the forbs *Sutera kraussiana*, *Hermannia quartiniana*, *Gerbera viridifolia* and *Athrixia angustissima*. The four grasses mentioned occur widespread over the higher rainfall areas of South Africa, whereas *Aster filifolius* and *Euryops annae* are often indicators of overgrazing and mismanagement of the vegetation in the higher rainfall areas of the centre of South Africa. These six species differentiate, however, positively between the Indigofero spinescentis-Rhoion erosae and the other Rhoetea erosae communities (table VI.4).

In the area around Aliwal North, where the grassland merges into the False Upper Karoo, and on protected sites between two close mountain ridges or in narrow troughs as far west as Bethulie, another association that is floristically related to the Indigofero spinescentis-Rhoion erosae occurs, namely the Blepharido-Rhoetum ass. nov. (fig. VI.4). The association again occurs on steep slopes, with a shallow, slightly acid to neutral lithosol, but does not seem to be associated with aspect or geological substrate. It has been recorded on Beaufort sandstones as well as on dolerite. The limiting habitat factors seem to be a complex of features resulting in a slightly mesic situation, although less mesic than, or different from, the situation in which the Indigofero spinescentis - Rhoion erosae communities occur.

Character species and differential species of the Blepharido-Rhoetum against the Indigofero spinescentis - Rhoion erosae communities are *Blepharis integrifolia*, *Argyrolobium lanceolatum* (d), *Lycium salinicolum* (d), *Sutera halimifolia* (d), *Dianthus basuticus* subsp. *basuticus* (d), *Aloe broomii* (d), *Schizoglossum linifolium*, *Limeum aethiopicum* (d), *Senecio hieracioides* (d), *Mariscus capensis* (d) and probably *Euphorbia aggregata*. Several of these species also occur in other communities of the class Rhoetea erosae. The most important woody plants in the Blepharido-Rhoetum are *Rhus erosa* and *Rhus undulata* var. *burchellii*. Some invading species of the Pentzio-Chrysocomion are constant in this association, but usually score only low cover-abundance ratings. The Blepharido-Rhoetum has a number of species in common with the Rhoo-Aloetum ferocis such as *Eustachys paspaloides*, *Enneapogon scoparius* and several others. These are mainly Rhoetea erosae species, but they are absent or virtually so from the Rhamno-Rhoetum, as has been mentioned above. Hence, they serve as positive differential species of the Blepharido-Rhoetum and the Rhoo-Aloetum ferocis as against the Rhamno-Rhoetum (table VI.4). The average number of species of the Blepharido-Rhoetum is 42.

The Blepharido-Rhoetum is usually two layered. Total cover averages about 55 per cent. There is a shrub and small tree layer, generally between 1 and 2,5 m high, but sometimes up to 4 m tall, covering about 30 per cent on the average, but occasionally up to 50 per cent. The groundlayer is between 0,50 and 0,70 m high, and covers usually about 25 per cent. In FOSBERG's physiognomic classification the community belongs to formation 2B1.2, evergreen broad sclerophyll steppe scrub.

A number of species are shared by the Indigofero spinescentis-Rhoion erosae communities and the Blepharido-Rhoetum and are lacking in the other Rhoetea erosae communities. Most of these species clearly indicate the more mesic situations required by these three Rhoetea erosae communities. Based on these floristic relationships, the Rhamno-Rhoetum, the Rhoo-Aloetum ferocis and the Blepharido-Rhoetum are combined into the order Grewio-Rhoetalia erosae ord. nov. The following species are characteristic or positively differential against the remainder of the Rhoetea erosae: the shrubs or small trees *Grewia occidentalis*, *Celtis africana* (d) and *Maytenus heterophylla*, the grasses *Elyonurus argenteus* (d), *Hyparrhenia hirta* (d), *Melica decumbens* (d) and *Ehrharta erecta*, the forbs *Berkheya discolor*, *Rhynchosia totta*, *Hermannia depressa* (d), *Gerbera piloselloides*, *Hibiscus aethiopicus*, *Polygala amatymbica* and the fern *Mohria caffrorum* (d) (table VI.4).

A considerable number of other species, which commonly occur in and are regarded as typical for most of the Rhoetea erosae communities, including the Grewio-Rhoetalia erosae, will be discussed below.

HEPBURN's (1919) account of the plant communities in the Herschel District illustrates floristic relationships between some of his "mountain formation" and the Grewio-Rhoetalia, but not to such an extent that they can be identified as being the same. Although it is not possible to assess with certainty from POTTS & TIDMARSH' (1937) descriptive account of a local vegetation complex near Bloemfontein the exact relationships of those communities with the presently described ones, it is clear that the community called by them "Koppie Bush" is floristically closely related to the Grewio-Rhoetalia erosae. MOSTERT's (1958) "Southeastern Slope-Community" is probably identical with POTTS & TIDMARSH' "Koppie Bush", and the latter is pertinently the same as MüLLER's (1970) "Grewio-Buddleia-Sociation".

The floristic affinities shown by the *Euclea crispa-Ehrharta erecta* Association described from the ravines of the northeastern Orange Free State by VAN ZINDEREN BAKKER Jr. (1971), to the Grewio-Rhoetalia erosae are very limited and suggest no direct relationships.

VI.4.3 The shrub communities of the False Upper Karoo (Rhoetalia ciliato - erosae)

The plains of the False Upper Karoo bear a monotonous, floristically poor vegetation, described in the previous chapter (VI.3) under the name Pentzio-Chrysocomion. The vegetation of the numerous hillsides in the area is varied, however, and richer in species. Particularly the abundance and variety of grasses and the occurrence of shrubs and small trees cause the conspicuous difference in appearance between the vegetation of the plains and that of the slopes.

In the area between Aliwal North and Skurwekop, on gentle slopes, from 3° to 6° and rarely up to 9°, where a shallow soil layer covers the underlying bedrock, which generally consists of Beaufort sandstones and mudstones, the Osteospermetum leptolobi ass. nov. is encountered (fig. VI.5). The soil is a sandy loam, usually only 0,05 to 0,10 m deep, which contains a large fraction of fine gravel and is always slightly acid, with a pH between 5,5 and 6,5. The association has the following character and differential species: the dwarf shrubs *Osteospermum leptolobum*, *Eriocephalus spinescens* (d), *Pentzia sphaerocephala*, *Phymaspermum parvifolium* and *Euryops empetrifolius*, which is less common. Another character species is *Euphorbia clavarioides*, which forms low but very compact, succulent cushions. Other species frequently encountered in this association are *Hibiscus marlothianus*, the prostrate woody plants *Aptosimum depressum* and *Nenax microphylla*, the grass *Aristida diffusa* var. *burkei* and the aizoaceous *Trichodiadema pomeridianum*. Also Pentzio-Chrysocomion species occur commonly and abundantly in the Osteospermetum leptolobi (table VI.5).

On slightly sandier and somewhat deeper soils on the gentle slopes, particularly west of Colesberg, the subassociation Osteospermetum leptolobi aptosimetosum marlothii subass. nov. is found (fig. VI.5). Differential species for this subassociation as against the typical form of the association are the spinous dwarf shrub *Aptosimum marlothii*, the small grass *Enneapogon brachystachyus* and the slender dwarf shrub *Polygala leptophylla*. The aizoaceous dwarf shrub *Limeum aethiopicum* is remarkably constant in this subassociation (table VI.5).

In both the typical form of the association and in the aptosimetosum marlothii shrubs are not often encountered. It is generally a two-layered vegetation dominated by dwarf shrubs. Total cover for the typical form of the association amounts to 45 per cent on the average, varying between 30 and 55 per cent, whereas in the aptosimetosum marlothii the total cover averages 25 per cent, varying between 10 and 35 per cent. The dwarf shrub layer varies in height between 0,30 and 0,60 m and usually accounts for the total cover value. A groundlayer of very low plants, up to 0,05 m in height, commonly covers only 5 per cent or less, although values of 20 per cent were sometimes recorded in the typical form of the association.

The Osteospermetum leptolobi typicum as well as the aptosimetosum marlothii belong to formation 2F1.2, evergreen narrow sclerophyll dwarf shrub steppe savanna, in FOSBERG's classification (1967).

The average number of species of the typical form of the Osteospermetum leptolobi is 19, and of the subassociation aptosimetosum marlothii 21.

The association comprises the *Chrysocoma tenuifolia-Nenax microphylla* and *Chrysocoma tenuifolia-Polygala leptophylla* Communities, preliminarily described from the vicinity of Bethulie by WERGER (1973a).

On the steep hillsides, with slopes generally between 15° and 30°, where the bedrock consists of dolerite, or less frequently of Beaufort sandstones interrupted by dolerite layers, the Stachyo-Rhoetum ass. nov. is found. The association is common in the area between Aliwal North and Petrusville, but also occurs infrequently further downstream on the slopes of doleritic inselbergs rising up from the plains formed by Ecca deposits (fig. VI.5). The association is mainly encountered on northerly facing slopes, although it might also occur on southerly facing slopes, which do not provide a mesic habitat. The soils on which the association is found are always shallow, loamy lithosols with a pH between 5,5 and 7,0.

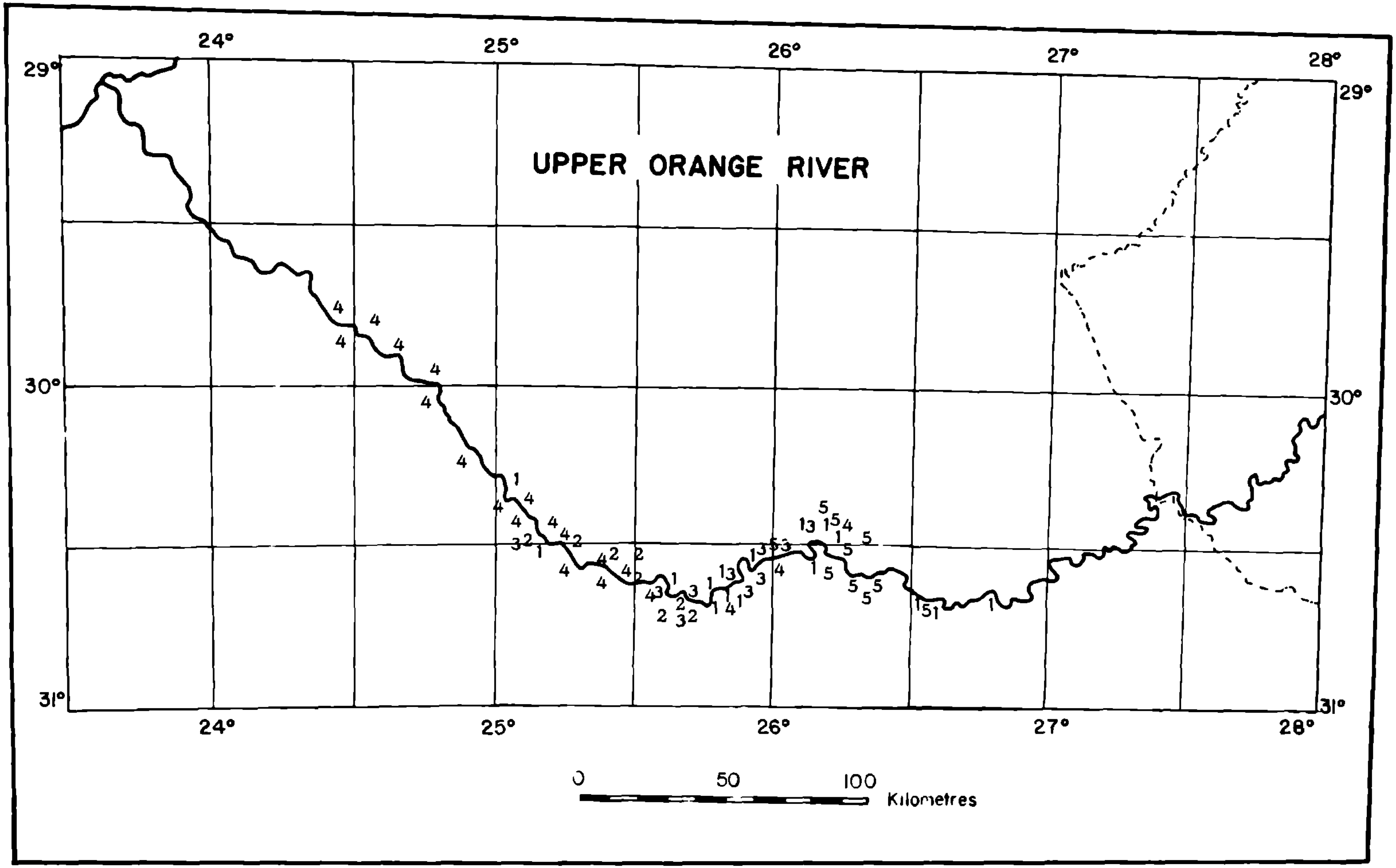


Fig. VI.5 Distribution of Hibisco marlothiani-Rhoion erosae in the study area. 1. Osteospermetum leptolobi typicum; 2. Osteospermetum leptolobi aptosimetosum marlothii; 3. Stachyo-Rhoetum polygaletosum; 4. Stachyo-Rhoetum hermannietosum candidissimae (*Salvia namaensis*-variant included); 5. Nanantho vittati-Rhoetum.

The Stachyo-Rhoetum is characterized by the following character and differential species: the gray forb *Stachys burchelliana* (d), the grass *Fingerhuthia africana* (d), the dwarf shrubs *Phyllanthus maderaspatensis* (d) and *Indigofera sessilifolia* (d), and the slender forb *Heliophila suavissima*. Many other species occur in the association, of which *Pegolettia retrofracta*, *Limeum aethiopicum*, *Sutera albiflora*, *Rhus ciliata*, *Aristida diffusa* var. *burkei*, *Asparagus suaveolens*, *Heteropogon contortus*, *Rhus undulata* var. *burchellii*, *Rhus erosa*, *Eustachys paspaloides* and several Pentzio-Chrysocomion species are amongst the commonest (table VI.5).

Two subassociations of the Stachyo-Rhoetum have been distinguished. The polygaletosum subass. nov. occurs mainly in the area between Aliwal North and Colesberg on slopes with predominantly a coarse gravelly soil, usually derived from dolerite and Beaufort sandstone drift (fig. VI.5). Positive differential species for this subassociation are *Polygala ephedroides* and *Polygala uncinata*. The average number of species of the polygaletosum is 32.

In the area between Colesberg and Petrusville the hermannietosum candidissimae subass. nov. is commonly encountered on dolerite (fig. VI.5). This subassociation is typified by a considerable number of differential species: the shrubs *Ehretia rigida*, *Rhigozum obovatum* and *Ziziphus mucronata*, the dwarf shrubs *Hermannia candidissima*, *Polygala leptophylla*, *Barleria rigida*, *Hermannia pulchra*, and possibly *Aptosimum marlothii*, the succulents *Talinum caffrum*, *Pachypodium succulentum* and *Senecio longiflorus* and the grass *Eragrostis chloromelas*. The high cover-abundance values scored by *Rhus undulata* var. *burchellii* in this subassociation are also typical, whereas *Rhus erosa* is relatively more important in the polygaletosum (table VI.5). *Ziziphus mucronata* shows a reduced vitality in this subassociation as compared with the riverine Zizipho-Acacietum karroo, in that it occurs always as rather small shrubs in the Stachyo-Rhoetum hermannietosum candidissimae and never as large trees as in the Zizipho-Acacietum karroo. The average number of species of this subassociation is 36.

West of Petrusville, where the relief is less pronounced and only isolated doleritic inselbergs break the monotonous Ecca landscape, a variant with *Salvia namaensis* occurs, mainly on the middle and upper parts of steep, southerly facing slopes (fig. VI.5). The variant is typified by the forb *Salvia namaensis*, and the differential species of the hermannietosum candidissimae also occur here, with the exception of *Polygala leptophylla*, *Pachypodium succulentum*, *Eragrostis chloromelas* and *Senecio longiflorus* (table VI.5). The average number of species of the *Salvia namaensis*-variant is 41.

Four relevés (89, 16, 65 and 38) could not be placed in either of these subassociations.

The Stachyo-Rhoetum consists usually of three vegetation layers, to which may be added, in the polygaletosum and the hermannietosum candidissimae, a very open layer of small trees of *Olea africana*, 5 to 6 m in height, covering up to 15 per cent. In the polygaletosum a shrub layer up to approximately 2 m in height, covering 10 per cent on the average, is always present. Further, there is a dwarf shrub and grass layer, measuring 0,50 to 0,60 m in height, with a range in cover from 20 to 75 per cent, and a ground-layer of less than 0,05 m high, covering between 5 and 40 per cent. The average total cover of the subassociation amounts to 60 per cent.

In the hermannietosum candidissimae the shrub layer is between 1 and 4 m high and covers usually 10 to 15 per cent, although values of 45 per cent are sometimes reached. The dwarf shrub and grass layer is 0,50 to 0,70 m high, covering between 20 and 35 per cent, whereas the groundlayer is up to 0,05 m high and usually covers less than 5 per cent. In the *Salvia namaensis*-variant the shrub layer also measures between 1 and 4 m in height, covering usually about 15 per cent. The dwarf shrub and grass layer is 0,80 m high, covering 35 to 40 per cent, largely due to the high cover-abundance of *Salvia namaensis*, whereas the groundlayer of 0,05 m high, usually covers less than 5 per cent.

In FOSBERG's classification both subassociations belong to formation 2B1.2, evergreen broad sclerophyll steppe scrub. The phases with scattered trees of *Olea africana* belong to formation 2D1.2, evergreen sclerophyll steppe savanna.

On the northerly facing Beaufort sandstone slopes, steeper than 10°, mainly in the area between Aliwal North and Bethulie, the Nanantho vittati - Rhoetum ass. nov. occurs (fig. VI.5). Rarely the association is encountered on southerly facing slopes, and in such cases the slopes are usually less than 10°. The soils on which the association is found, are shallow lithosolic, sandy loams, with a pH between 5,5 and 7,0. The soils contain a large fraction of coarse gravel. The succulents *Nananthus vittatus* and *Haworthia tesselata*, the grasses *Brachiaria serrata* (d) and *Hyparrhenia hirta* (d) and the forbs *Dicoma macrocephala* (d) and *Asclepias fruticosa* (d) are character or positive differential species for the association. *Hyparrhenia hirta* is particularly abundant on sites where a gully is initiated. Among the many other species occurring in the association are *Rhus ciliata*, *Euclea coriacea*, *Aristida diffusa* var. *burkei*, *Heteropogon contortus*, *Rhus undulata* var. *burchellii*, *Rhus erosa*, *Eragrostis curvula*, *Cymbopogon plurinodis* and several Pentzio-Chrysocomion species the most important. It is further remarkable that *Tarchonanthus camphoratus* and *Euclea crispa* are virtually absent from the association (table VI.5).

The Nanantho vittati-Rhoetum usually consists of three vegetation strata: a groundlayer a dwarf shrub and grass layer and a shrub layer. Rarely a low tree layer of *Olea africana*, 5 to 6 m tall, covering less than 10 per cent, is present. The shrub layer is between 1 and 4 m high and covers 15 per cent on the average, although values of up to 25 per cent are occasionally reached. The dwarf shrub and grass layer is usually 0,70 m to 0,80 m high, and when *Hyparrhenia hirta* is present, up to 1,20 m high, covering 40 per cent on the average, but with a range of cover values from 15 to 70 per cent. The groundlayer less than 0,05 m high, rarely covers more than 5 per cent. Total cover of the vegetation layers averages 50 per cent, but is occasionally as low as 15 per cent.

In FOSBERG's classification (1967) the phytocoenoses of the Nanantho vittati-Rhoetum belong mainly to formation 2B1.2, evergreen broad sclerophyll steppe scrub. The phytocoenoses with trees of *Olea africana* belong to formation 2D1.2, evergreen sclerophyll steppe savanna, whereas the open phases, without trees, belong to formation 2E1.2, evergreen sclerophyll shrub steppe savanna.

The communities preliminarily described by WERGER (1973a) under the name *Rhus erosa*-

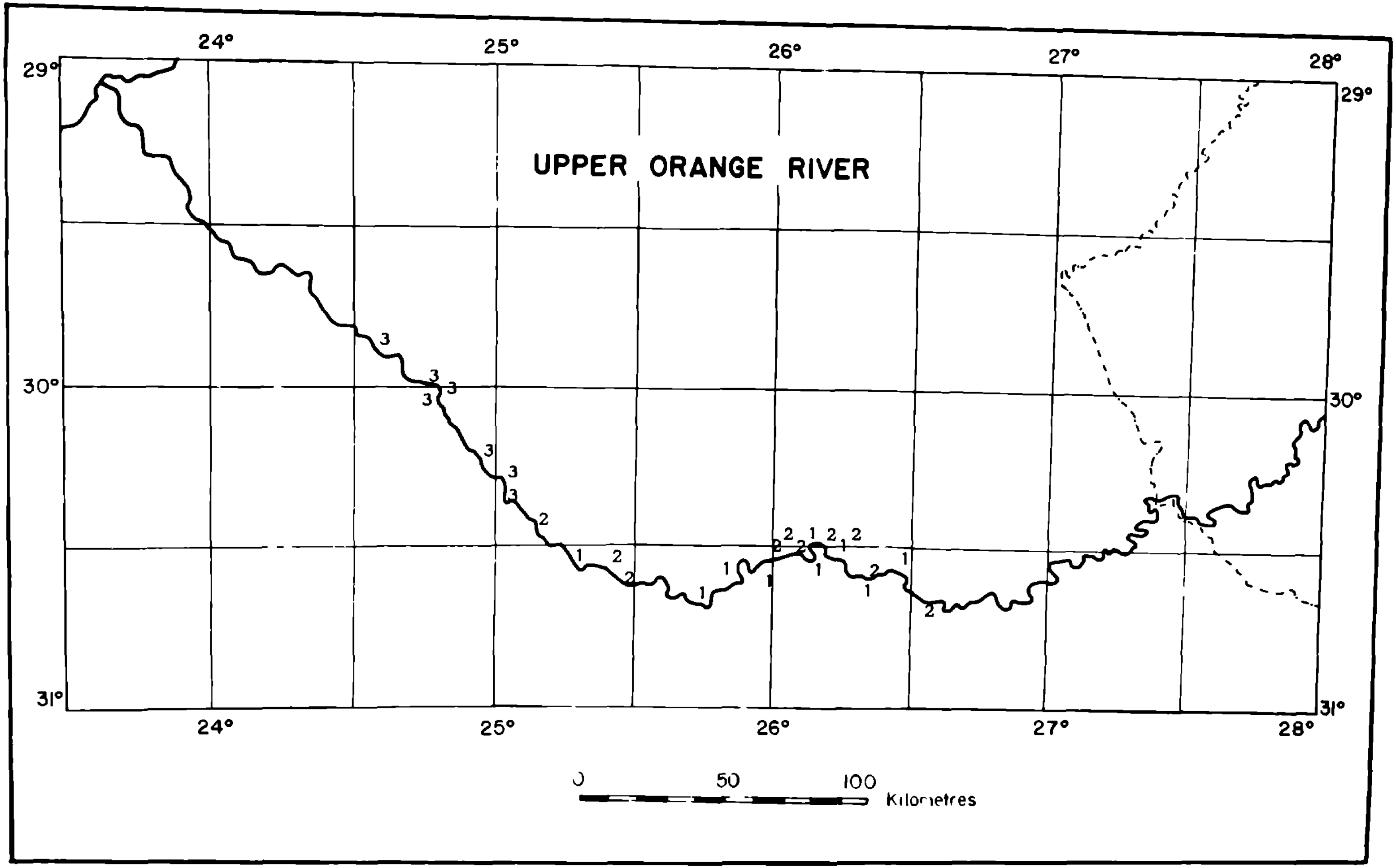


Fig. VI.6 Distribution of Mayteno polyacanthae-Oleetum africanae typicum (1) and chamareetosum (2) and of Setario lindenbergianae-Buddleietum salignae (3) in the study area.

Rhynchelytrum repens Group of Communities, from the vicinity of Bethulie are included in the Nanantho vittati-Rhoetum, described at present.

The Osteospermetum leptolobi, the Stachyo-Rhoetum and the Nanantho vittati-Rhoetum have a number of species in common, which are absent or nearly so from the other Rhoetea erosae communities. On the basis thereof these associations are combined into the alliance Hibisco marlothiani-Rhoion erosae all. nov. Character and differential species are the dwarf shrubs *Pegolettia retrofracta* (d), *Melolobium microphyllum, Helichrysum zeyheri, Helichrysum lucilioides* (d), *Eriocephalus pubescens* (d), *Thesium spartioides* and *Trichodiadema pomeridianum,* and the forbs *Hibiscus marlothianus, Aptosimum depressum, Chascanum pinnatifidum, Blepharis villosa* and *Anacampseros lanigera.* The species *Helichrysum lucilioides, Blepharis villosa* and *Anacampseros lanigera* have not been recorded in the Nanantho vittati-Rhoetum, whereas *Hibiscus marlothianus, Aptosimum depressum, Thesium spartioides, Eriocephalus pubescens* and *Trichodiadema pomeridianum* were only seldomly recorded in that association. On these grounds the distinction of a separate suballiance formed by the Osteospermetum leptolobi and the Stachyo-Rhoetum can be considered, but is regarded as superfluous here.

The Hibisco marlothiani-Rhoion erosae includes all communities on shallow soils on the slopes of Beaufort sandstones and mudstones and dolerite in the False Upper Karoo and some isolated localities further westwards, where conditions are not mesic.

In the entire area between Aliwal North and Petrusville, steep dolerite slopes, over 10°, with an aspect mainly between southeast and southwest, occur. The soil is shallow, loamy and rocky, and its pH between 5,5 and 6,5. These less xeric sites form the habitat of the Mayteno polyacanthae-Oleetum africanae ass. nov. Character and differential species of this association are the low trees or shrubs *Maytenus polyacantha* and *Celtis africana* (d), the forbs *Asparagus laricinus* (d), *Pelargonium aridum, Senecio hieracioides* (d) and perhaps *Crassula setulosa,* and the fern *Mohria caffrorum* (d). *Stachys burchelliana* can also occur in this association, but is not as typical as in the Stachyo-Rhoetum or the Setario lindenbergianae-Buddleietum salignae. Species that are also important in the association are, for example, *Rhus erosa, Rhus ciliata, Sutera halimifolia, Eragrostis curvula, Eustachys paspaloides, Diospyros lycioides* subsp. *lycioides, Tarchonanthus camphoratus* and several others (table VI.5).

The association consists of two subassociations. On sheltered sites the typical form of the association occurs. *Olea africana* and *Rhus undulata* var. *burchellii* are very important in this community. On the less sheltered, more xeric sites the chamareetosum subass. nov. occurs, for which *Chamarea capensis* is differential species. Typical for the chamareetosum are also the high cover-abundance values reached here by *Aristida diffusa* var. *burkei, Diospyros austro-africana* and *Lightfootia albens.* The average number of species of both subassociations amounts to 39 (table VI.5). The distribution of the two subassociations in the study area is shown in fig. VI.6.

Relevé 44 is not fully representative. It was situated in a steep gully where runn-off of the slope concentrated after thunderstorms, washing away the shallow soil and the shallow-rooted plants.

The typical form of the Mayteno polyacanthae-Oleetum africanae consists of four vegetation layers: a small tree layer, 5 to 6 m in height with a range in cover from 15 to 80 per cent; a shrub layer, 1 to 3 m high, covering between 25 and 60 per cent; a dwarf shrub and grass layer, 0,60 to 0,70 m high, usually covering about 30 per cent and an extremely sparse groundlayer less than 0,05 m high. Total cover of this community averages 80 to 85 per cent. In FOSBERG's classification (1967) this subassociation belongs to formation 1A1.6(a), mesophyllous evergreen broad sclerophyll forest, or when the tree layer is open, to formation 2A1.2(b), mesophyllous evergreen sclerophyll steppe forest.

The chamareetosum consists of three vegetation layers: a shrub layer of 1 to 3 and sometimes 4 m high, usually covering approximately 30 per cent; a dwarf shrub and grass layer, 0,60 to 0,70 m in height, generally covering between 50 and 55 per cent, and a groundlayer, 0,05 m in height, seldomly covering more than 5 per cent. Total cover of this subassociation amounts to about 65 to 70 per cent. The chamareetosum belongs to FOSBERG's (1967) formation 2B1.2, evergreen broad sclerophyll steppe scrub.

The preliminarily described *Rhus erosa-Stachys burchelliana* Community and one of the *Olea africana - Maytenus heterophylla* Communities, both occurring in Tussen die Riviere Game Farm, O.F.S. (WERGER, 1973a) are included in the Mayteno polyacanthae-Oleetum africanae.

On the isolated, doleritic inselbergs downstream of Petrusville, and also on dolerite slopes a few miles upstream of Petrusville, the Setario lindenbergianae - Buddleietum salignae ass. nov. occurs (fig. VI.6). The typical habitat of this association is formed by the southerly or westerly facing steep slopes, over 20°, just below the summits of the mountains. The soils consist of shallow sandy loams with a pH between 6,0 and 7,0. Coarse gravel and large boulders are abundant in this habitat. Character and differential species of the association are the grass *Setaria lindenbergiana*, the shrubs *Buddleia saligna* and *Osyris lanceolata* (d), the forbs *Asparagus striatus* (d) and *Solanum retroflexum* and the pachycaulous (cf. CORNER, 1954) or tuft tree *Cussonia paniculata* (d). Other species of occasional importance in the association are *Stachys burchelliana*, *Salvia namaensis*, *Themeda triandra*, *Rhus undulata* var. *burchellii*, *Sporobolus fimbriatus*, *Euclea crispa*, *Digitaria eriantha*, and a few others (table VI.5). The number of species recorded in the relevés of this association varies considerably, depending on whether the relevé was taken on a somewhat sheltered or on an exposed site. For sheltered sites the average number of species of the association is about 38; for exposed sites this number is lower.

The association is four or three-layered. Occasionally there is an open tree layer of *Cussonia paniculata*, up to 6 or 7 m tall, covering less than 10 per cent. The shrub layer is up to 4,5 m high, covering between 10 and 25 per cent. The dwarf shrub and grass layer is up to 1 m in height and often covers 50 per cent or more. The groundlayer less than 0,05 m high, is always very sparse. Total cover varies between 35 and 75 per cent, depending on the amount of large boulders present at each locality. When an open tree layer is present, the Setario linderbergianae-Buddleietum salignae belongs to FOSBERG's (1967) formation 2D1.2, evergreen sclerophyll steppe savanna. Otherwise the association belongs to formation 2B1.2, evergreen broad sclerophyll steppe scrub. Phytocoenoses with an exceptionally dense growth of *Setaria lindenbergiana* might belong to formation 1J1.2, evergreen broad sclerophyll low savanna.

A number of species are common to the Hibisco marlothiani-Rhoion erosae, the Mayteno polycanthae-Oleetum africanae and the Setario lindenbergianae-Buddleietum salignae, which are absent from the Grewio-Rhoetalia erosae (tables VI.4, VI.5). Therefore, the three first mentioned syntaxa are combined into the Rhoetalia ciliato-erosae ord. nov., characterized by the following species: the dwarf shrubs and forbs *Limeum aethiopicum* (d), *Sutera albiflora, Sutera halimifolia, Rhus ciliata, Nenax microphylla* and *Lotononis laxa,* the shrub *Euclea coriacea* and the succulent *Aloe broomii.*

Thus, the order Rhoetalia ciliato-erosae comprises largely the shrub communities of the hillsides of the False Upper Karoo, whereas the order Grewio-Rhoetalia erosae comprises mainly the shrub communities of the hillsides of the more temperate grassland region east of the False Upper Karoo. Since the Rhoetalia ciliato-erosae are contact communities of the Hermannio coccocarpae-Nestleretum confertae, which occur on the deeper soils on the plains of the False Upper Karoo, the Rhoetalia ciliato-erosae are more heavily intruded by Pentzio-Chrysocomion species than the Grewio-Rhoetalia erosae. Apart from being contact communities this might be due to greater similarity in climatic conditions between the Hermannio coccocarpae-Nestleretum confertae and the Rhoetalia ciliato-erosae than between the former and the Grewio-Rhoetalia erosae.

The restriction of the shrub communities in these semi-wet to semi-arid areas to slopes with shallow, rocky soils is ascribed by WALTER (1962) to the particular soil structure and soil moisture regime of these soils, as compared to the deep loamy soils of the plains. The conditions on the slopes favour deep and extensively rooting, woody vegetation, whereas on the plains plants with intensive, shallow root systems are favoured.

Some of the communities described by POTTS & TIDMARSH (1937) in general terms, are, although not identical to certain communities described at present,probably Rhoetalia ciliato-erosae communities. Particularly the communities which they name "Koppie Scrub" and *Rhus ciliata - Themeda triandra* Community show considerable floristic affinities to the Rhoetalia ciliato-erosae. Similar considerations seem to apply to some of MOSTERT's (1958) "Randjie Veld Communities" and to MÜLLER's (1970) "Dry Grassland Sociations".

The Rhoetalia ciliato-erosae and the Grewio-Rhoetalia erosae share a large number of species and are combined into the class Rhoetea erosae cl. nov. The following species typify this syntaxon: the trees and shrubs *Rhus erosa, Rhus undulata* var. *burchellii, Diospyros austro-africana, Diospyros lycioides* subsp. *lycioides, Olea africana, Tarchonanthus camphorathus* and *Euclea crispa*; the dwarf shrubs *Lightfootia albens, Selago albida, Hermannia cuneifolia* var. *glabrescens* and *Lantana rugosa*; the grasses *Aristida diffusa* var. *burkei, Heteropogon contortus, Themeda triandra, Eragrostis curvula, Eustachys paspaloides, Sporobolus fimbriatus, Cymbopogon plurinodis, Enneapogon scoparius, Digitaria eriantha* and *Rhynchelytrum repens*; the forbs *Hibiscus pusillus, Helichrysum dregeanum, Solanum supinum, Solanum coccineum, Dianthus basuticus* subsp. *basuticus, Argyrolobium lanceolatum* and *Anthospermum rigidum*; the leaf-succulents *Adromischus rupi-*

cola and *Cotyledon decussata-orbiculata* complex and the ferns *Cheilanthes hirta, Cheilanthes eckloniana* and *Pellaea calomelanos* (tables VI.4, VI.5).

A number of these Rhoetea erosae character species do not occur as abundantly in the Grewio-Rhoetalia erosae as in the Rhoetalia ciliato -erosae. Others do not occur in all the Grewio-Rhoetalia erosae communities, but differentiate positively, as mentioned above, between the Rhoo-Aloetum ferocis and the Blepharido-Rhoetum on the one hand and the Rhamno-Rhoetum on the other (table VI.4).

With the exception of *Aristida diffusa* var. *burkei,* the Rhoetea erosae species are only infrequently present in the Osteospermetum leptolobi. This association is conspicuously open and occurs on gentle slopes. These gentle slopes are,together with the plains of the False Upper Karoo, considerably more overgrazed than the steeper slopes. This may account for the frequent absence of many species, particularly grasses. The general floristic composition of the Osteospermetum leptolobi, however, justifies the classification of this association in the Rhoetalia ciliato - erosae and consequently in the Rhoetea erosae.

In the class Rhoetea erosae all the shrub communities of the shallow soils, occurring on hillsides in the False Upper Karoo and the *Cymbopogon-Themeda* Veld, and in which several species of *Rhus*, particularly *Rhus erosa* and *Rhus undulata* var. *burchellii*, are dominant or conspicuous, are combined into a single syntaxon. The western boundary of the distribution area of the Rhoetea erosae coincides with the boundary between the Sudano-Zambesian and the Karoo-Namib floral Regions in the Upper Orange River area.

VI.5 THE SHRUB AND DWARF SHRUB COMMUNITIES OF THE ROCKY SOILS OF THE WESTERN UPPER ORANGE RIVER VALLEY (PENTZIETEA INCANAE)

VI.5.1 Introduction

Downstream of Petrusville the scenery in the Upper Orange River area changes abruptly. Emerging from a narrow trough through a dissected countryside that commences near Colesberg, the Orange River reaches, just west of Petrusville, a flat, monotonous landscape, where the only relief consists of a few isolated inselbergs. The substrate is formed by Ecca and Dwyka deposits and, in the western-most section of the Upper Orange River, by Ventersdorp lavas. Only the upper parts of the inselbergs consist of Beaufort deposits and dolerite (see Chapter II.3). Thick calcrete layers occur over extensive stretches of land and pans are found throughout the area (compare Chapters II.4, II.5). Soils are usually lithosols or of a sandy loam type except in some localities north of the river, and in lees south of the river where thick deposits of Kalahari sand have accumulated (compare Chapter II.5). The vegetation of this area is classified by ACOCKS (1953) mainly as False Arid Karoo and False Orange River Broken Veld. It is characterized by a large number of species typical of the Karoo-Namib floral Region and particularly by what are called by ACOCKS (1953) the "white desert grasses" or grasses of the genus *Stipagrostis*. In small xeric pockets this vegetation occurs infrequently in the area east of Petrusville, upstream as far as Skurwekop, but west of Petrusville it is the main type. This vegetation extends westward considerably beyond the Upper Orange River area, changing gradually into the shrubby vegetation of Bushmanland and the dwarf shrub savanna (GIESS, 1971) of South West Africa.

The following syntaxa will be discussed in this section (the relationships between the syntaxa are symbolized by the code in front of the syntaxa names):

II	Pentzietea incanae
IIA	Pentzio incanae-Rhigozetalia trichotomi
IIA1	Enneapogono scabri-Rhigozion obovati
IIA1a	Zizipho-Rhigozetum obovati
(1)	cheilanthetosum ecklonianae
(2)	inops
IIA1b	Melhanio rehmannii-Hermannietum spinosae
IIA2	Zygophyllion gilfillani
IIA2a	Monechmatetum incani
(1)	typicum
(2)	pentzietosum calcareae
IIA2b	Nestlero humilis-Pteronietum sordidae
(1)	typicum
(2)	stipagrostietosum ciliatae
IIB1a	Eriocephalo-Eberlanzietum

VI.5.2 The communities

On the slopes of the deep and narrow valley trough and the surrounding mountains between Skurwekop and Petrusville and on several slopes of inselbergs in the area from Petrusville to Hopetown, the Zizipho-Rhigozetum obovati ass. nov. occurs (fig. VI.7). Its habitat consist nearly always of dolerite slopes, sometimes interrupted by layers of Beaufort or Ecca sandstones, mudstones or shales covered by a shallow lithosol, which contains a large amount of gravel, fine as well as coarse, and has a pH varying from slightly acid to slightly alkaline (5,5 to 8,0). The association is characterized by a number of differential species, several of which are Rhoetea erosae species which reach their westernmost limit here and occur together with species typical of more arid areas. These species are the small trees and shrubs *Ziziphus mucronata* (d), *Rhus undulata* var. *burchellii* (d), *Acacia karroo* (d), *Olea africana* (d), *Diospyros austro-africana* (d), *Hermannia cuneifolia* var. *glabrescens* (d) and *Rhus ciliata* (d), the grasses *Digitaria eriantha* (d) and *Themeda triandra* (d), the forbs *Hibiscus pusillus* (d),*Pollichia campestris* (d), *Argyrolobium lanceolatum* (d), *Polygala asbestina* (d), *Asparagus striatus* (d), *Asclepias fruticosa* (d) and *Stachys burchelliana* (d) and possibly the aerial hemiparasite *Viscum rotundifolium* (d). *Ziziphus mucronata* and *Acacia karroo,* which occur as large trees in the riverine forests, occur only as rather small shrubs in the Zizipho - Rhigozetum obovati and thus show a reduced vitality in this association. Amongst the many other species occurring in the association, several grasses can be important, such as *Aristida diffusa* var. *burkei, Enneapogon scaber, Enneapogon scoparius, Heteropogon contortus, Fingerhuthia africana, Sporobolus fimbriatus, Aristida congesta, Aristida curvata* and *Eragrostis lehmanniana.* Also the shrubby *Rhigozum obovatum, Rhigozum* *trichotomum* and *Boscia albitrunca*, and the dwarf shrub *Chrysocoma tenuifolia* can be of importance in this association (table VI.6).

Two subassociations of the Zizipho-Rhigozetum obovati are distinguished. On steeper slopes, inclined at more than 15°, the subassociation cheilanthetosum ecklonianae subass. nov. is encountered, whereas on slopes with an inclination of up to 7° and rarely up to 15° the subassociation inops subass. nov. is found. The cheilanthetosum ecklonianae is usually found on middle and upper slopes, since here the inclination is usually greater than on the lower slopes (cf. FAIR, 1948), where the subassociation inops more often occurs. There seems to be no clear correlation between slope direction (aspect) and the occurrence of these subassociations. The cheilanthetosum ecklonianae is typified by the following differential species: the ferns *Cheilanthes eckloniana* and *Pellaea calomelanos*, the grasses *Cymbopogon plurinodis*, *Eustachys paspaloides* and *Rhynchelytrum repens*, the dwarf shrubs *Sutera albiflora* and *Melolobium microphyllum*, the forbs *Hibiscus marlothianus*, *Chascanum pinnatifidum*, *Sutera halimifolia*, *Solanum coccineum*, *Hermannia pulchra* and *Anthospermum rigidum*, the sedge *Mariscus capensis* and the leaf-succulent *Aloe broomii*. The shrub *Rhigozum obovatum* regularly reaches high cover-abundance values in this subassociation (table VI.6). The average number of species of the cheilanthetosum ecklonianae is 44.

The subassociation inops is generally not so rich in species as the cheilanthetosum ecklonianae. It seems to be typified by the infrequent occurrence of the shrub *Tarchonanthus camphoratus* and the dwarf shrub *Selago albida*, the former being usually abundant when it occurs (table VI.6). The average number of species of this subassociation is 33.

Relevé 520 is situated at Torquay, away from the main distribution area of the association in a sheltered ravine on a southeast-facing dolerite slope.

In both subassociations of the Zizipho-Rhigozetum obovati the vegetation usually consist of three strata. A small tree and shrub layer is from 1 to 3,5 and sometimes 4 m high and covers usually less than 10 per cent. A dwarf shrub and grass layer, up to 0,75 m in height, covers about 40 per cent and occasionally up to 75 per cent. The groundlayer, less than 0,05 m high, is always sparse. Total cover averages 40 per cent but ranges from 20 to 80 per cent.

Although some of the shrubs and small trees are evergreen, most are deciduous. Hence, the Zizipho-Rhigozetum obovati usually belongs in FOSBERG's (1967) classification to formation 2B2.3, microphyllous deciduous steppe scrub, or 2B2.4, deciduous thorn steppe scrub, or, the dense phases, to formation 1K2.3, microphyllous deciduous shrub savanna, or 1K2.4, mesophyllous deciduous thorn shrub savanna.

Downstream of Hopetown, until the confluence with the Vaal River, the Orange River has cut a moderately deep valley with convex sides through andesitic Ventersdorp lava (comp. Chapter II.4). The slopes of the valley sides are seldom over 15° and bear a shallow, rocky lithosol of loamy sand with a large fraction of coarse gravel. The pH of this lithosol is usually between 5,5 and 6,5. The same soil is found on the lava plateau just outside the valley trough. On these shallow lava-derived lithosols, without correlation

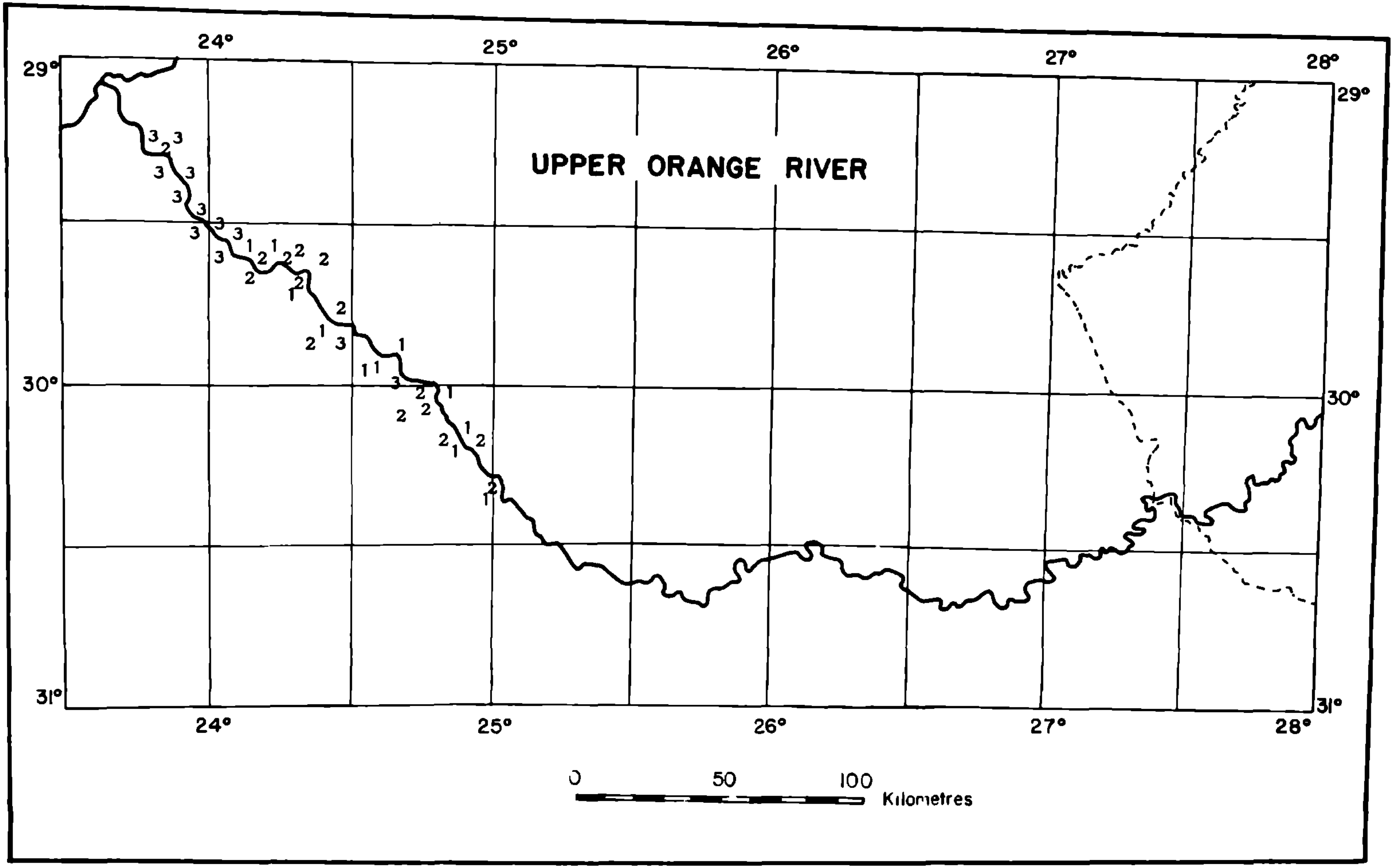


Fig. VI.7 Distribution of Enneapogono scabri-Rhigozion obovati in the study area. 1. Zizipho-Rhigozetum obovati cheilanthetosum ecklonianae; 2. Zizipho-Rhigozetum obovati inops; 3. Melhanio rehmannii-Hermannietum spinosae.

with slope direction, the Melhanio rehmannii-Hermannietum spinosae ass. nov. occurs (fig. VI.7). It is a shrub community characterized by the following character and differential species: the small tree and shrub *Acacia tortilis* subsp. *heteracantha* (d) and *Grewia flava* (d), which find in this association their optimum in the karroid area but which are wide-spread further north (cf. LEISTNER & WERGER, 1973), the grasses *Oropetium capense* (d) and *Eragrostis denudata* (d), both of which possess extreme desiccation-tolerant mature foliage (GAFF, 1971), and the dwarf shrubs and forbs *Hermannia spinosa*, *Lasiocorys capensis* (d), *Melhania rehmannii*, *Blepharis mitrata*, *Barleria lichtensteiniana*, *Hermannia desertorum*, *Mestoklema tuberosum*, *Hoodia gordonii* (d) and *Aloe claviflora* (d), the latter three species being succulents. Amongst the most important other species occurring in this association are the grasses *Aristida diffusa* var. *burkei* and *Enneapogon scaber*, the shrubs *Rhigozum trichotomum*, *Acacia mellifera* subsp. *detinens*, *Rhigozum obovatum* and *Phaeoptilum spinosum* and several Pentzio-Chrysocomion species. The average number of species of the association is 37 (table VI.6).

Relevés 348 and 371 are transitional between the Melhanio rehmannii-Hermannietum spinosae and the Zizipho-Rhigozetum obovati. They are situated on hot, steep dolerite slopes, inclined 19° and 14° respectively, upstream of the main distribution area of the Melhanio rehmannii-Hermannietum spinosae, towards the higher rainfall area.

The Melhanio rehmannii-Hermannietum spinosae is usually three-layered. A small tree and shrub layer, 1 to 3 m tall, exceptionally up to 4 m tall, covers generally between 3 and 30 per cent, although occasionally values of up to 50 per cent are reached. The dwarf shrub and grass layer usually less than 0,50 m in height, covers 30 per cent on the average, with a range from about 10 to 40 per cent. The groundlayer, less than 0,05 m high usually covers less than 5 per cent.

In FOSBERG's (1967) classification the association belongs alternatively to formations 2E2.3, microphyllous deciduous shrub steppe savanna, or 2E2.4, deciduous thorn shrub steppe savanna, or to formations 2B2.3, microphyllous deciduous scrub, or 2B2.4, deciduous thorn steppe scrub, depending on the density of the shrub layer and whether *Rhigozum trichotomum* or *Acacia mellifera* subsp. *detinens* is dominant.

The Zizipho-Rhigozetum obovati and the Melhanio rehmannii-Hermannietum spinosae have a number of species in common, which do not occur in the other Pentzietea incanae communities. Based upon these floristic similarities the two associations are combined into the syntaxon Enneapogono scabri-Rhigozion obovati all. nov. The shrub *Rhigozum obovatum*, the grasses *Aristida diffusa* var. *burkei* (d), *Enneapogon scaber*, *Enneapogon scoparius* (d), *Enneapogon cenchroides* (d), *Sporobolus fimbriatus* (d) and *Heteropogon contortus* (d) and the dwarf shrubs and forbs *Phyllanthus maderaspatensis*, *Pegolettia retrofracta* (d), *Corbichonia decumbens*, *Lantana rugosa* (d), *Indigofera sessilifolia*, *Hermannia candidissima*, *Solanum supinum* (d), *Senecio longiflorus* (d), *Helichrysum lucilioides* (d), *Abutilon austro-africana*, *Aptosimum depressum* (d) and *Sansevieria aethiopica* are character and positive differential species for the alliance. A number of these species are more common in and characteristic of the Rhoetea erosae communities, but serve here as good positive differential species between this alliance and the other

Pentzietea incanae communities (compare Chapter VI.4). In the Enneapogono scabri-Rhigozion obovati the shrub and grass dominated communities of the False Arid Karoo and False Orange River Broken Veld in the Upper Orange River area are united (table VI.6).

Downstream of Petrusville the Monechmatetum incani ass. nov. occurs (fig. VI.8). The association is found on shallow, rocky, lithosols of loamy sand, often with a pH of 8,2, on the plateaux and gentle slopes, rarely sloping more than 5^{o}, where some concentration of occasional sheet flow occurs, such as in initiating gullies or sometimes on the lower pediment slopes, with inclinations of up to 10^{o} or slightly more. It also occurs on sites, where the lava or calcrete plateau is overlain by a thin layer of Kalahari sand, usually less than 0,40 m thick, and where sheet flow is somewhat concentrated. Here the pH of the sandy top soil is also generally between 8,0 and 8,2. The Monechmatetum incani has two character species, the dwarf shrubs *Monechma incanum* and *Pentzia lanata.* Some Pentzio-Chrysocomion species and *Enneapogon brachystachyus, Pentzia incana, Phaeoptilum spinosum, Aptosimum marlothii, Rhigozum trichotomum* and a few other species can also be important in the association (table VI.6).

Two subassociations of the Monechmatetum incani can be clearly distinguished. On the rocky loamy sand on the plateaux or pediplains and on the lower pediment slopes the subassociation typicum subass. nov. is found, while on the plateaux covered with Kalahari sand the subassociation pentzietosum calcareae subass. nov. occurs. The subassociation typicum is relatively rich in species as compared with the pentzietosum calcareae. Species commonly occurring in the typicum and virtually absent from the pentzietosum calcareae are the shrubby *Acacia mellifera* subsp. *detinens, Boscia albitrunca* and *Ehretia rigida,* the grass *Fingerhuthia africana* and the dwarf shrubs and forbs *Limeum aethiopicum, Cyphocarpha angustifolia, Hermannia spinosa, Nestlera humilis* and *Plinthus karooicus.* Apart from the virtual absence of these species from the pentzietosum calcareae, this latter subassociation is characterized by the relatively high cover-abundance values reached here by *Pentzia calcarea* and perhaps by *Aptosimum marlothii* and *Eragrostis lehmanniana* (table VI.6). The average number of species of the pentzietosum calcareae is 16 and of the typicum 24.

A number of plants in this association are generally correlated with calcareous soils, such as *Monechma incanum* (cf. LEISTNER & WERGER, 1973) and *Pentzia calcarea.* The HCl-reaction on soil samples taken in the Monechmatetum incani only occasionally proved positive, but as ZÓLYOMI (1963) explained, a more complete soils analysis is desirable since a high content of Ca-ions could then possibly have been correlated with the occurrence of lime-indicator species.

The Monechmatetum incani consists of either two or three vegetation layers. A shrub layer of usually *Acacia mellifera* subsp. *detinens, Rhigozum trichotomum, Phaeoptilum spinosum Ehretia rigida* and small trees of *Boscia albitrunca,* often only up to 2 m in height, can be present and cover up to 40 per cent, although it usually covers only 5 per cent or less. A dwarf shrub and grass layer, 0,30 to 0,75 m high, is always present, generally covering between 20 and 30 per cent. A groundlayer, less than 0,05 m high, is always very sparse.

In FOSBERG's (1967) physiognomic classification system both the subassociations belong

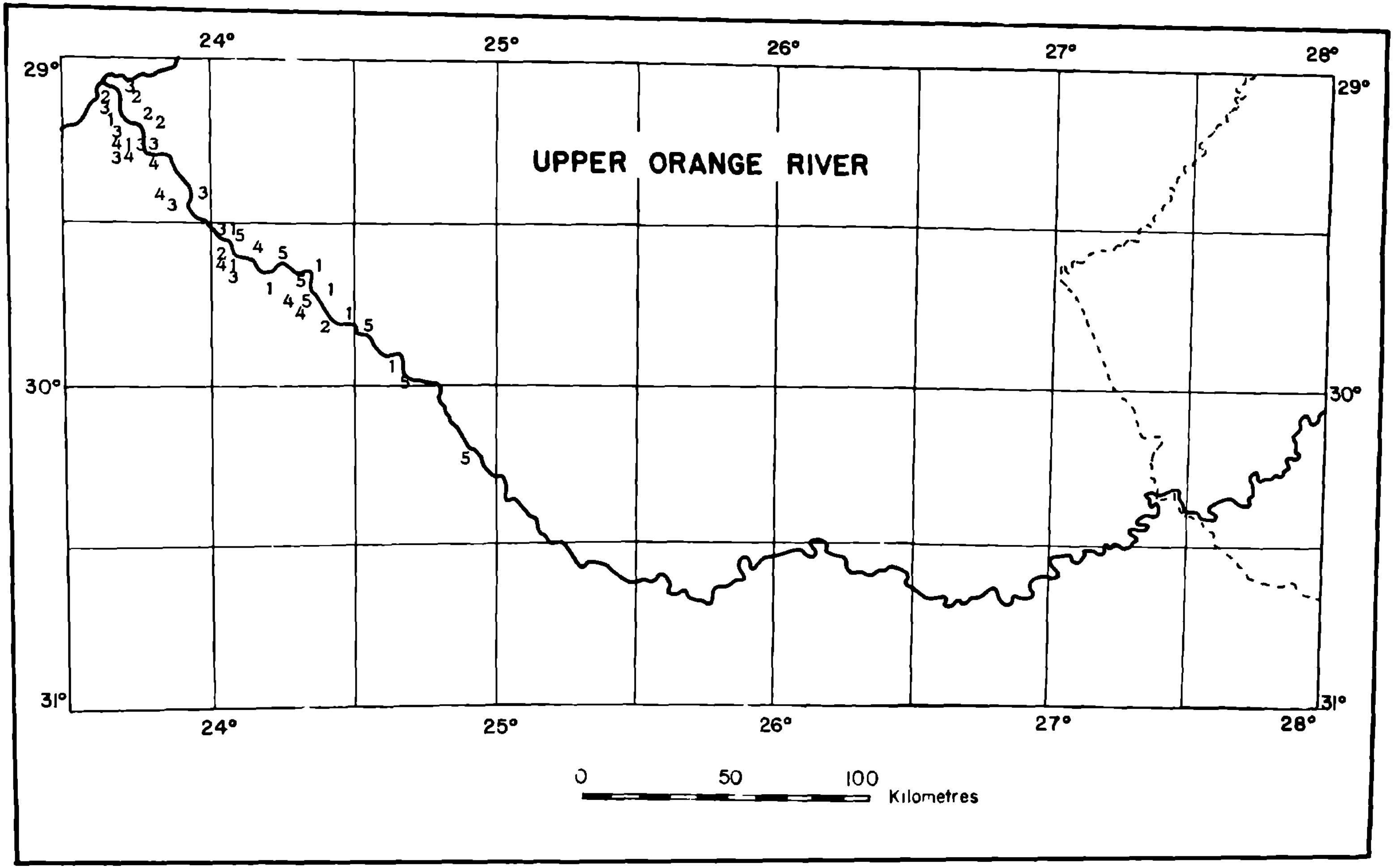


Fig. VI.8 Distribution of Zygophyllion gilfillani and Eriocephalo-Eberlanzietum in the study area. 1. Monechmatetum incani typicum; 2. Monechmatetum incani pentzietosum calcareae; 3. Nestlero humilis-Pteronietum sordidae pentzietosum calcareae; 4. Nestlero humilis-Pteronietum sordidae typicum; 5. Eriocephalo-Eberlanzietum.

to formations 2B2.3, microphyllous deciduous steppe scrub, or 2B2.4, deciduous thorn steppe scrub, to formations 2E2.3, microphyllous deciduous shrub steppe savanna, or 2E2.4, deciduous thorn shrub steppe savanna, or to formation 2C1.4, microphyllous evergreen dwarf steppe scrub, depending on whether *Rhigozum trichotomum* or *Acacia mellifera* subsp. *detinens* forms the shrub layer or whether the shrub layer is absent.

Downstream from Orania the Ecca sandstones or Ventersdorp lava plateaux are frequently covered with a layer of sand, which contains a fair amount of fine gravel and pebbles, often agates, jasper, chalcedony, and other minerals and rock. Calcareous concretions constitute an important component of these soils, and often the sand and gravel are completely cemented into a thick calcrete stratum. On these calcareous-rich soils on the flat to slightly sloping pediplains, which have a pH varying between 8,0 and 8,6 and always show a strong positive HCl-reaction, the Nestlero humilis-Pteronietum sordidae ass. nov. is found (fig. VI.8). It is typified by the following character and differential species: the dwarf shrubs *Nestlera humilis forma, Pteronia sordida, Hermannia pulverata, Aptosimum albomarginatum, Aptosimum spinescens* (d), *Lasiocorys capensis* (d), *Lycium pilifolium, Massonia microloma, Monechma desertorum* and possibly *Monechma distichotrichum,* the grass *Eragrostis truncata* and the succulent *Euphorbia aequoris.* Other species of importance in the association are *Enneapogon brachystachyus, Zygophyllum gilfillani, Pentzia calcarea, Aptosimum marlothii, Chrysocoma tenuifolia* and a few others (table VI.6).

Two subassociations of the Nestlero humilis-Pteronietum sordidae have been distinguished: the stipagrostietosum ciliatae subass. nov. and the typicum subass. nov. The stipagrostietosum ciliatae occurs on the sand-covered plains of sandstone or lava, in which unconsolidated calcrete occurs as concretions and nodules. The soil is less than 1 m deep. More often this habitat is found just below the minor break in the nearly horizontal lava plateau, forming a small scarp, where the Orange River incision starts. Just below these minor scarps there is a lee, such that a thin layer of sand is deposited. The subassociation is typified by the occurrence of a considerable number of differential species of which the grass *Stipagrostis ciliata* and the woody plants *Rhigozum trichotomum, Acacia mellifera* subsp. *detinens* and *Boscia albitrunca* are the most important. Other differential species are *Lessertia pauciflora, Fagonia minutistipula, Fingerhuthia africana, Pteronia glauca, Polygala asbestina* and, to a lesser extent, *Acacia tortilis* subsp. *heteracantha* (table VI.6). The average number of species of the stipagrostietosum ciliatae is 25.

The Nestlero humilis-Pteronietum sordidae typicum occurs on the flats, where the compactly cemented calcrete layer forms the surface. This subassociation virtually lacks the abovementioned differential species, but is characterized by the higher constancy and abundance with which *Pentzia calcarea* occurs and also by the somewhat higher constancy of the Pentzio-Chrysocomion species, *Eragrostis lehmanniana* and *Gnidia polycephala* (table VI.6). The average number of species of this subassociation is 19.

The stipagrostietosum ciliatae often consists of three vegetation strata. The uppermost layer of woody plants, such as *Acacia mellifera* subsp. *detinens, Acacia tortilis* subsp. *heteracantha, Rhigozum trichotomum, Phaeoptilum spinosum* and *Boscia albitrunca,* is usually less than 4 m in height and can cover, if present, up to 30 per cent. The dwarf shrub and grass layer, 0,30 to 0,70 m high, generally covers about 30 per cent, whereas the groundlayer, less than 0,05 m high, covers usually less than 5 per cent. In FOSBERG's (1967) classification the stipagrostietosum ciliatae belongs to formations 2B2.3, microphyllous deciduous steppe scrub, or 2B2.4, deciduous thorn steppe scrub, to formations 2E2.3, microphyllous deciduous shrub steppe savanna, or 2E2.4, deciduous thorn shrub steppe savanna, or to formation 2C1.3, evergreen narrow sclerophyll dwarf steppe scrub, depending on whether *Rhigozum trichotomum* or *Acacia mellifera* subsp. *detinens* is dominating the shrub layer and whether a shrub layer is absent.

The typicum is two-layered. A dwarf shrub and grass layer 0,20 to 0,45 m in height, covering between 15 and 35 per cent, is accompanied by a groundlayer,less than 0,05 m high, covering between 5 and 45 per cent. The occasional high cover values of the groundlayer are largely due to the high percentage of cover sometimes reached by *Eragrostis truncata* and *Enneapogon brachystachyus*. In FOSBERG's (1967) classification this subassociation belongs to formation 2C1.3, evergreen narrow sclerophyll dwarf steppe scrub.

The Monechmatetum incani and the Nestlero humilis-Pteronietum sordidae are combined in the Zygophyllion gilfillani all. nov. based on the following character and differential species: the dwarf shrubs *Zygophyllum gilfillani* and *Pentzia calcarea* (d) and the grass *Stipagrostis obtusa* (d) (table VI.6). In this alliance the shrub and dwarf shrub dominated communities occurring in the Upper Orange River area of the False Arid Karoo and the False Orange River Broken Veld (ACOCKS, 1953), on calcium-rich substrates, are combined.

The shrubs *Rhigozum trichotomum*, *Acacia mellifera* subsp. *detinens* and *Ehretia rigida*, the low tree *Boscia albitrunca*, the dwarf shrubs and forbs *Cyphocarpha angustifolia*, *Pteronia glauca* and *Nestlera humilis* and the grasses *Fingerhuthia africana* and *Cenchrus ciliaris* are common to the Enneopogono scabri-Rhigozion obovati and the Zygophyllion gilfillani and absent from the following Pentzietea incanae community (table VI.6). Therefore these alliances are combined into the Pentzio incanae-Rhigozetalia trichotomi ord. nov. and the above-mentioned species are regarded as character species of this syntaxon.

Between Skurwekop and Hopetown, on level to slightly sloping plains of dolerite or Ecca sandstones overlain by a slightly acid to neutral, 0,25 m to approximately 1 m deep soil of loamy sand, which contains a small fraction of fine gravel, the Eriocephalo-Eberlanzietum ass. nov. occurs (fig. VI.8). It is an open community, characterized by the spiny, aizoaceous succulent *Eberlanzia spinosa*, the spiny dwarf shrubs *Eriocephalus spinescens* (d) and *Aptosimum spinescens* (d), the dwarf shrub *Hermannia comosa* (d) and by *Salsola glabrescens* (d), which occurs either as a shrub or a dwarf shrub. Very common in this association are also the shrub *Phaeoptilum spinosum* and the grass *Enneapogon brachystachyus*. *Stipagrostis ciliata* and *Stipagrostis obtusa* are occasionally abundant (table VI.6). The average number of species of the association is 24.

Total cover values of the Eriocephalo-Eberlanzietum are usually rather low, and generally range from 15 to 35 per cent. Three vegetation strata are present. The open shrub layer, consisting mainly of *Phaeoptilum spinosum* is 1 to 2 m high and covers usually less than 5 per cent. The dwarf shrub and grass layer, up to 0,60 m high, covers between 10 and 25 per cent. The groundlayer, less than 0,10 m in height, can be either sparse or covers up to 20 per cent, depending mainly on the abundance of *Enneapogon brachystachyus*. In FOSBERG's (1967) classification the association belongs to formations 2E2.4, deciduous thorn shrub steppe savanna, or 3B2.2, deciduous desert thorn-scrub.

The *Eberlanzia spinosa-Euphorbia mauritanica* Community described from the vicinity of Bloemfontein by POTTS & TIDMARSH (1937), MOSTERT (1958) and MÜLLER (1970) is syntaxonomically not related to the Eriocephalo-Eberlanzietum.

The Pentzio incanae-Rhigozetalia trichotomi and the Eriocephalo-Eberlanzietum are floristically related to one another and placed together in the class Pentzietea incanae cl. nov. The shrub *Phaeoptilum spinosum* the dwarf shrubs *Pentzia incana, Barleria rigida, Limeum aethiopicum, Aptosimum marlothii, Aptosimum leucorrhizum, Plinthus karooicus, Thesium hystrix, Eriocephalus pubescens* and *Polygala hottentotta* and the grass *Enneapogon brachystachyus* characterize this class (table VI.6). The Pentzietea incanae communities contain regularly, apart from a number of Pentzio-Chrysocomion species and Rhoetea erosae species, several accompanying species, of which *Aristida curvata, Dicoma macrocephala, Asparagus suaveolens, Tragus berteronianus, Eragrostis porosa* and *Geigeria filifolia* are the most common ones.

It is remarkable that the Enneapogono scabri-Rhigozion obovati, in particular the Zizipho-Rhigozetum obovati cheilanthetosum ecklonianae, contain so many Rhoetea erosae species, and the classification of this syntaxon in the Pentzietea incanae might seem debatable. Apart from those Rhoetea erosae species occurring in the communities of the Enneapogono scabri-Rhigozion obovati, many others typical of that class are absent, such as *Rhus erosa, Eragrostis curvula, Lightfootia albens, Diospyros lycioides* subsp. *lycioides, Dianthus basuticus* subsp. *basuticus, Nenax microphylla, Helichrysum zeyheri* and several more. Other Rhoetea erosae species, although occurring in the Enneapogono scabri-Rhigozion obovati communities, score consistently considerably lower cover-abundance values here as compared with the Rhoetea erosae. Such species are for example, *Rhus undulata* var. *burchellii, Aristida diffusa* var. *burkei, Themeda triandra*, and others.

Furthermore, with SCHWICKERATH's (1931) "Gruppenabundanzmethode" the strong floristic affinities of the Enneapogono scabri-Rhigozion obovati, as well as of the Zizipho-Rhigozetum obovati separately, with the other communities of the Pentzietea incanae become apparent and this fully justifies the inclusion of the alliance in that class.

The Pentzietea incanae comprise the shrub and dwarf shrub communities on rocky, usually shallow soils of the semi-arid False Upper Karoo and False Orange River Broken Veld. It forms the natural continuation in the series from Grewio-Rhoetalia erosae (Chapter VI.4.2), through Rhoetalia ciliato-erosae (Chapter VI.4.3) to Pentzietea incanae, which parallels the gradient from temperate mesic to hot semi-arid conditions. Whereas the Rhoetea erosae constitutes a class of Sudano-Zambesian communities, the Pentzietea incanae communities are Karoo-Namib.

From the southern Kalahari the Aizoo-Indigoferetum auricomae LEISTNER et WERGER 1973 as well as the Sporobolo lampranthi-Zygophylletum tenuis LEISTNER et WERGER 1973 were described. Although it is likely that these two associations belong to the Pentzietea incanae, information on the vegetation in the area interjacent to the southern Kalahari and the Upper Orange River is necessary to make a decision in this respect.

The Zygophyllo pubescentis-Stipagrostietum obtusae VOLK et LEIPPERT 1971, described from calcareous sites in the vicinity of Windhoek, South West Africa, was placed by the authors in the class Rhigozetea trichotomi VOLK 1964 nom. nud., but it likely belongs to the Pentzietea incanae, although not to the Pentzio incanae-Rhigozetalia trichtomi.

As in later publications by VOLK (1966a) and VOLK & LEIPPERT (1971) it was not indicated which lower syntaxa were meant to be included in the class Rhigozetea trichotomi it is left a nomen nudum.

Several dwarf shrubs of the Pentzietea incanae, particularly species of the genera *Pteronia, Plinthus, Salsola* and *Eriocephalus*, show a remarkable way of propagation by splitting their stems when they become older. This phenomenon was studied in detail by THERON (1964; THERON et al., 1968) on *Plinthus karooicus*. It was found, that excentric secondary thickening followed by the formation of secondary periderm bridges, running lengthwise through stem and root, ultimately cause the splitting of the main stem into a number of independent plants which are able to grow individually.

VI.6 THE GRASSLAND COMMUNITIES ON KALAHARI SAND (STIPAGROSTION prov.)

As far upstream as Colesberg, but mainly in the area downstream of Petrusville, small to fairly large pockets of wind-blown Kalahari sand occur in lees and on the plains. These habitats characteristically bear a vegetation dominated by white *Stipagrostis* grasses. Because of severe overgrazing for just over a century the dominance of *Stipagrostis* species locally has given way to an abundant growth of *Rhigozum trichotomum* in particular. The same species, but even more so *Acacia mellifera* subsp. *detinens*, and to some extent *Acacia tortilis* subsp. *heteracantha*, have been involved in the bush encroachment in the communities on the hillsides with shallow soils, discussed in the previous Chapter (Pentzietea incanae). According to the early travellers, these hillsides, and even more the plains covered with Kalahari sand were grassier and had not such a large woody component a century and a half ago as at present (see Chapter II.6). As pointed out in Chapter II.6, bush encroachment is a result of the disturbance of the equilibrium between woody vegetation and grass by overgrazing and trampling to the advantage of the woody vegetation, particularly as far as available soil moisture is concerned (cf.WALTER, 1939, 1954b, c, 1962; WALTER & VOLK 1954; VOLK, 1966b; GIESS, 1968). *Rhigozum trichotomum* usually occurs in these habitats in extensive colonies with a closed front, because it reproduces mainly by forming suckers from rhizomes (LEISTNER, 1967 ; GIESS, 1968; LEISTNER & WERGER, 1973).

In the Upper Orange River area two associations on Kalahari sand, both dominated by *Stipagrostis* species, have been distinguished (table VI.7; fig. VI.9).

Where dolerite or Ecca sandstones are overlain by a layer of slightly loamy Kalahari

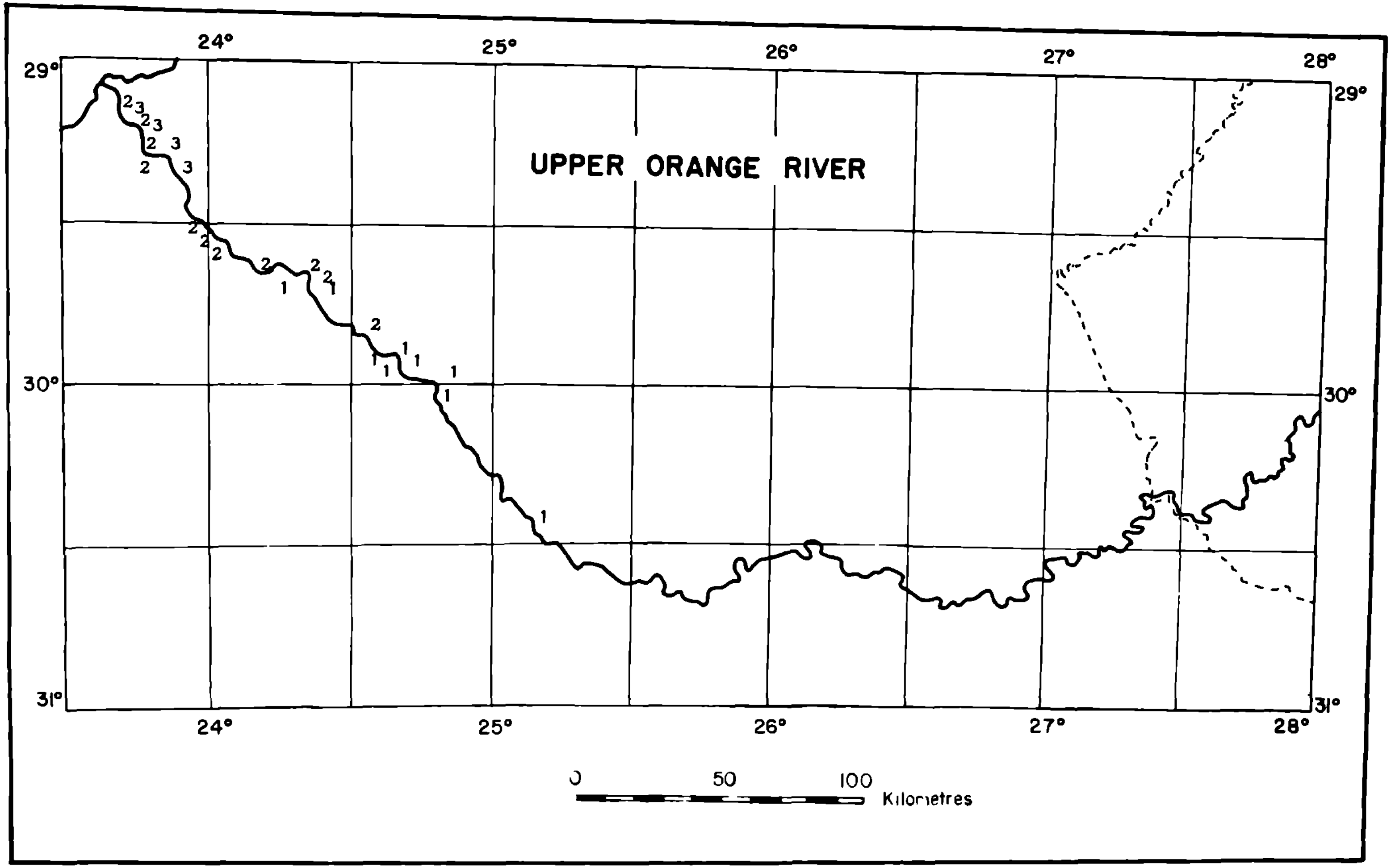


Fig. VI.9 Distribution of Stipagrostion in the study area. 1. Enneapogono brachystachyi-Stipagrostietum; 2. Pentzio calcareae-Stipagrostietum typicum; 3. Pentzio calcareae-Stipagrostietum acacietosum giraffae.

sand, possibly somewhat mixed with wind-blown alluvial sand, occurs the Enneapogono brachystachyi-Stipagrostietum ass. nov. Where this association is found, the sand layer is always over 0,40 m and often more than 1 m deep. It usually contains a small fraction of fine gravel and occasionally also some calcareous concretions. The soil is relatively compact as compared with the majority of Kalahari sand deposits, and has a pH of mainly 6,0 to 7,0 although when calcareous nodules are present, the pH might be as high as 8,4. These situations occur mainly in the area just downstream of Petrusville. Character and differential species of the association appear to be *Enneapogon brachystachyus* (d) and probably *Nestlera laxa,* while *Stipagrostis obtusa* and *Stipagrostis ciliata* are abundant and *Plinthus cryptocarpus* is relatively frequent. Dense stands (facies) of *Rhigozum trichotomum* occur occasionally. Some other species that are often found in this association are the pioneer grasses *Tragus berteronianus, Eragrostis porosa, Eragrostis lehmanniana* and *Aristida congesta* and the dwarf shrub *Chrysocoma tenuifolia* (table VI.7). The average number of species of the association is 11.

The Enneapogono brachystachyi-Stipagrostietum consists of two or three vegetation layers. A shrub layer of *Rhigozum trichotomum,* sometimes with *Phaeoptilum spinosum,* up to 1,50 m high, can cover up to about 25 and sometimes even more per cent. The dwarf shrub and grass layer, 0,50 or 0,70 m in height, ranges in cover from as low as 5 per cent to as high as 50 per cent. The groundlayer of less than 0,10 m high, can cover up to 15 per cent. In FOSBERG's (1967) classification the Enneapogono brachystachyi-Stipagrostietum belongs to formation 2B2.3, microphyllous deciduous steppe scrub, when *Rhigozum trichotomum* is present. Otherwise it belongs to formation 2F1.2, evergreen narrow sclerophyll dwarf shrub steppe savanna.

In the area downstream of Hopetown there are several localities, where the Kalahari sand deposit measures 1 m or more in thickness. Usually the underlying substratum consists of a thick, compactly cemented, calcareous layer and sometimes small calcareous nodules are found in the sand layer, which does not contain a loamy fraction as is the case where the Enneapogono brachystachyi-Stipagrostietum occurs. The pH of the sand varies from 7,0 to 8,4. The soil regularly gives a positive HCl-reaction, but if not so, a large amount of Ca-ions might still be expected in the soil, as pointed out in Chapter VI.5 and by ZóLYOMI (1963). On these sands the Pentzio calcareae-Stipagrostietum ass. nov. is encountered. This association is characterized by the shrub or small tree *Acacia tortilis* subsp. *heteracantha* (d), the dwarf shrubs *Pentzia calcarea* (d), which is often abundant, *Aptosimum marlothii* (d), *Eriocephalus pubescens* (d) and *Hermannia comosa* (d) and the herbaceous plant *Nolletia arenosa.* The grasses *Stipagrostis obtusa* and *Stipagrostis ciliata* are again constant and often abundant. *Rhigozum trichotomum* frequently occurs in the typical dense colonies. Other commonly encountered species in this association include *Tragus berteronianus, Phaeoptilum spinosum, Dicoma macrocephala, Chrysocoma tenuifolia, Aristida congesta* and *Eragrostis lehmanniana.* This description is characteristic for the typical form of the Pentzio calcareae-Stipagrostietum. Near Douglas, however, on sites where the Kalahari sand is at least 2 m deep, the subassociation acacietosum giraffae subass. nov. occurs (fig. VI.9), typified by the occurrence of the large evergreen tree *Acacia giraffae* and perhaps the occurrence of *Polygala leptophylla* and the shrub *Lycium salinicolum* under the trees. This vegetation is part of the Kalahari Thornveld invaded by Karoo, Veld Type 17 (ACOCKS, 1953). The average number of species of the typical form of the association is 14 and of the acacietosum giraffae 20 (table VI.7).

The Pentzio calcareae-Stipagrostietum in its typical form consists of two or three vegetation layers, depending on whether a shrub layer formed by *Rhigozum trichotomum*, *Phaeoptilum spinosum* and/or *Acacia tortilis* subsp. *heteracantha* is present or not. If present, the shrub layer is generally less than 2 m in height and covers up to 50 per cent. The dwarf shrub and grass layer is up to 0,60 m high, covering usually between 20 and 50 per cent. A groundlayer less than 0,05 m high, is always extremely sparse. In FOSBERG's (1967) classification this community belongs to formation 2B2.3, microphyllous deciduous steppe scrub, when *Rhigozum trichotomum* dominates the shrub layer; to formation 2E2.4, deciduous thorn shrub steppe savanna, when *Rhigozum trichotomum* is absent, but the shrub layer is formed by *Acacia tortilis* subsp. *heteracantha* or *Phaeoptilum spinosum*; and to formations 2C1.3, evergreen narrow sclerophyll dwarf steppe scrub, or 2F1.2, evergreen narrow sclerophyll dwarf shrub steppe savanna, when there is no shrub layer.

The Pentzio calcareae-Stipagrostietum acacietosum giraffae consists of four vegetation strata: on open tree layer, up to 8 m tall, covering 5 per cent or less; an open shrub layer, up to 2 m in height, also covering less than 5 per cent; a dwarf shrub and grass layer, up to 0,80 m high, covering between 20 and 40 per cent, and a very sparse groundlayer, less than 0,05 m in height. In FOSBERG's (1967) system the acacietosum giraffae belongs to formation 2D1.3, evergreen microphyll steppe savanna.

The inclusion of this subassociation into the Pentzio calcareae-Stipagrostietum is a clear example of the combination of structurally different syntaxa into one higher syntaxon on the basis of floristic criteria, as also applied by VAN DONSELAAR (1965) in the savannas of Suriname.

The names Enneapogono brachystachyi-Stipagrostietum and Pentzio calcareae-Stipagrostietum suggest vicariant associations occurring in geographically distinct areas. This is, however, not the case. The two associations occur in different habitats in the same area, but since *Stipagrostis obtusa* and *Stipagrostis ciliata* are typical and the most conspicuous plants, and since no other species are suitable for nomenclatural purposes, the present names have been chosen.

The Kalahari sand accumulation forms the largest uninterrupted surface of sand in the world (WELLINGTON, 1955) and in the southern part of it, communities dominated by species of *Stipagrostis* are wide-spread. From the area delineated by LEISTNER (1967) as the southern Kalahari, a number of such communities are described (LEISTNER & WERGER, 1973), such as the Peliostomo-Stipagrostietum obtusae LEISTNER et WERGER 1973, two *Monechma incanum-Stipagrostis ciliata* Communities, the Hirpicio-Asthenatheretum LEISTNER et WERGER 1973 and the Stipagrostietum amabilis LEISTNER et WERGER 1973.

The Peliostomo-Stipagrostietum obtusae, the two *Monechma incanum-Stipagrostis ciliata* Communities, the Enneapogono brachystachyi-Stipagrostietum and the Pentzia calcareae-Stipagrostietum have the species *Stipagrostis obtusa*, *Stipagrostis ciliata* and *Plinthus cryptocarpus* in common, and can therefore be combined into the alliance Stipagrostion prov., with the above listed three species as character species. When more data become available from the area lying between the Upper Orange River and the southern Kalahari, it is possible that more associations should be included in the Stipagrostion.

Although floristically related to the Stipagrostion, the Stipagrostietum amabilis and the Hirpicio echini-Asthenatheretum cannot be included in that alliance.

It is likely that, when enough data become available, the open grassy communities occurring on Kalahari sands in the arid and semi-arid areas of South West Africa, Botswana and South Africa, including Bushmanland, can be combined into a single syntaxon.

VI.7 MINOR COMMUNITIES

Apart from the communities described in Chapters VI.2-6, a number of other communities occur in the Upper Orange River area, which are generally of limited spatial extent. Some of them, like those along roads and railway lines, and those occurring on the remnants of collapsed termitaria, have not been sampled, although some general observations have been made.

In the area upstream of Aliwal North, the roadside and railroadside communities often represent facies or fragments of the grassland communities described in Chapter VI.2. Some species like *Themeda triandra* and *Eragrostis curvula* are often abundant, and the phytocoenoses contain a considerable number of apophytes and neophytes. Total cover values are often relatively high in these communities, since the roadside communities are hardly grazed at all and also more water is available to them owing to run-off from the asphalt.

Between Aliwal North and Petrusville the roadside and railroadside communities are similar to the Hermannio coccocarpae-Nestleretum confertae eragrostietosum curvulae and to the various Rhoetalia ciliato-erosae communities described in Chapters VI.3 and VI.4, although often grasses are more abundant. Apophytes and neophytes, like *Chloris virgata, Argemone subfusiformis* and *Salsola kali,* are locally abundant.

Downstream of Petrusville roadside and railroadside communities usually represent facies and fragments of Pentzietea incanae and Stipagrostion communities, described in Chapters VI.5 and VI.6. Locally again species like *Chloris virgata, Argemone subfusiformis, Salsola kali, Aristida curvata* and also *Psilocaulon absimile* can be abundant.

Particularly on the plains covered with deep sandy loams, on which the Hermannio coccocarpae-Nestleretum confertae occurs, termitaria are frequent. Those that are inhabited are bare, but around their fringes and on the remnants of collapsed ones, *Sporobolus fimbriatus* and *Cynodon hirsutus* can be rather abundant, while *Asparagus suaveolens* is also encountered quite regularly on these habitats.

The plains with deep soils of sandy loam, between Aliwal North and Petrusville, have occasionally shallow depressions and damp sites where run-off concentrates, and where the topsoil is slightly acid. Here a closed community with mat-forming grasses and dwarf shrubs is found. Relevé 276 represents this community, that might be called the *Cynodon-Pentzia* Community. The dwarf shrub layer of the *Cynodon-Pentzia* Community is 0,20 m high and covers approximately 5 per cent, whereas the grass layer is about 0,10 m high and covers 80 per cent. In FOSBERG's (1967) classification this community belongs to formation 1H1.3, open evergreen microphyllous dwarf scrub.

Also between Aliwal North and Petrusville in wide pan-like depressions or on eroding fans with a brackish, deep compact surface soil of sandy loam or loamy sand, with a pH between 7,5 and 8,2 the *Pentzia-Eragrostis truncata* Community occurs (table VI.7.2).

TABLE VI.7.1 CYNODON-PENTZIA COMMUNITY

Relevé no.	276
SL	30° 37'
EL	25° 25'
Total cover (%)	80
Total no. of species	10
Pentzia globosa	1.2
Lycium salinicolum	+.2
Salsola glabrescens	+.2
Cynodon incompletus	4.4
Panicum stapfianum	1.3
Urochloa panicoides	1.2
Eragrostis curvula	1.2
Eragrostis obtusa	1.2
Mariscus capensis	+.2
Atriplex semibaccata	+.3

The community consists of two vegetation layers: a dwarf shrub and taller grass layer, up to 0,40 m in height, covering between 10 and 50 per cent, and a layer of mat-forming grasses and very low plants, 0,05 m high, covering up to 30 per cent. In FOSBERG's (1967) classification this community belongs to formation 2C1.3, evergreen narrow sclerophyll dwarf steppe scrub.

Between Bethulie and the vicinity of Petrusville in wide, nearly level washes, where a slightly concentrated run-off occasionally occurs, and the loamy soil with a pH of between 7,0 and 8,0 contains a calcareous fraction, the *Pentzia-Zygophyllum incrustatum* Community occurs (table VI.7.3). The community is two-layered. There is a dwarf shrub and grass layer of 0,15 to 0,45 m tall, covering 5 to 35 per cent, and a groundlayer, less than 0,05 m high, covering up to 15 per cent. In FOSBERG's (1967) system the community belongs to formations 2C1.3, evergreen narrow sclerophyll dwarf steppe scrub, or 2F1.2, evergreen narrow sclerophyll dwarf shrub savanna.

It is uncertain whether the *Cynodon-Pentzia* Community, the *Pentzia-Eragrostis truncata* Community and the *Pentzia-Zygophyllum incrustatum* Community are floristically sufficiently related to the Hermannio coccocarpae-Nestleretum confertae that they can be combined into one syntaxon.

TABLE VI.7.2 PENTZIA-ERAGROSTIS TRUNCATA COMMUNITY

Relevé no.	161	23	285	558	Sociability
SL	30° 35'	30° 32'	30° 35'	29° 50'	
EL	26° 27'	25° 53'	25° 16'	24° 34'	
Total cover (%)	25	65	10	65	
Total no. of species	6	15	17	5	
Pentzia globosa	+	2b	2a	4	1-2
Salsola glabrescens	2b	+	1	+	2
Chrysocoma tenuifolia	1	2b	r		1-2
Lycium salinicolum	1	1	+		2
Asparagus suaveolens		+	+	1	2
Hertia pallens			+	+	2
Nestlera conferta		+	+		2
Eragrostis truncata		3	+	+	3
Eragrostis lehmanniana	+	+	+		2
Tragus koelerioides	+	+	+		2
Eragrostis obtusa		+	+		2

further occurring in relevé 23: *Berkheya pinnatifida* (+), *Trichodiadema pomeridianum* (1), *Aptosimum depressum* (r), *Hermannia argentea* (r), *Indigofera alternans* (+); relevé 285: *Eriocephalus spinescens* (+), *Euphorbia mauritanica* (+), *Aristida congesta* (+), *Gazania krebsiana* (+), *Schizoglossum linifolium* (+), *Talinum caffrum* (+).

Between Petrusville and Hopetown on the plains formed by Ecca sandstones and shales, wide drainage lines or wide, shallow, dry streambeds occur occasionally. The soil is

TABLE VI.7.3 PENTZIA-ZYGOPHYLLUM INCRUSTATUM COMMUNITY

Relevé no.	72	13	397	557	Sociability
SL	30° 40'	30° 38'	29° 48'	29° 48'	
EL	25° 46'	25° 41'	24° 33'	24° 32'	
Total cover (%)	50	20	5	60	
Total no. of species	15	11	5	9	
Zygophyllum incrustatum	1	1	1	1	2
Salsola glabrescens	r	1	1	+	2
Pentzia globosa	2b	2a		3	1-2
Asparagus suaveolens	1		+	1	2
Drosanthemum sp.			+	+	1
Chrysocoma tenuifolia	r	1			1-2
Gazania krebsiana	+	+			2
Lycium salinicolum	+	+			2

further occurring in relevé 72: *Eragrostis truncata* (2a), *Eragrostis lehmanniana* (+), *Sporobolus fimbriatus* (+), *Aptosimum depressum* (+), *Aster muricatus* (+), *Talinum caffrum* (+), *Hermannia resedaefolia* (+), *Berkheya pinnatifida* (r); relevé 13: *Limeum aethiopicum* (+), *Plinthus karooicus* (+), *Cynodon hirsutus* (+), *Tragus koelerioides* (+), *Eriocephalus spinescens* (r); relevé 397: *Sporobolus pyramidatus* (+); relevé 557: *Delosperma ornatulum* (+), *Chloris virgata* (3), *Aristida curvata* (+), *Enneapogon brachystachyus* (+).

a loamy sand, with a considerable amount of fine gravel and sometimes a few calcareous nodules. The pH is usually between 8,2 and 8,6 and the soil gives a strong positive HCl-reaction. In this habitat the *Lycium prunus-spinosa* Community occurs (table VI.7.4). It is an open community with three vegetation layers. The shrub layer is usually not more than 1,50 m high and covers less than 10 per cent. The dwarf shrub and grass layer, 0,30 to 0,75 m high, covers usually between 5 and 20 per cent and the groundlayer, less than

TABLE VI.7.4 LYCIUM PRUNUS-SPINOSA COMMUNITY

Relevé no.	353	398	365	367	369	370	413	Sociability
SL	30° 30'	29° 49'	29° 51'	29° 49'	29° 49'	29° 49'	29° 45'	
EL	24° 39'	24° 32'	24° 30'	24° 28'	24° 27'	24° 27'	24° 22'	
Total cover (%)	20	7	20	10	30	15	30	
Total no. of species	22	13	21	16	29	11	8	
Lycium prunus-spinosa	1	1	+	1	+	2a	2a	2
Salsola glabrescens	1	1	2a	2a	+	2a	2a	2
Zygophyllum incrustatum		+	+			1		2
Drosanthemum sp.	+	+	1					1-2
Blackiella inflata	+	+						1-2
Aster burkei	+			1				2
Psilocaulon absimile		1	+					2
Pentzietea incanae species								
Enneapogon brachystachyus	+	+	+	+	+	+		2
Pentzia incana	2a		+			+		1-2
Barleria rigida	+			+	+			1-2
Pentzia lanata			+	1	1			1-2
Fingerhuthia africana				+	+			2
Thesium hystrix				+	+			2
Hermannia spinosa	+			+				2
Phaeoptilum spinosum			+		1			2
Pentzia-Chrysocomion species								
Lycium salinicolum	+	+	2a	+	+		2a	2
Aristida congesta	+		+		+			1-2
Chrysocoma tenuifolia	r		+		1			1-2
Pentzia globosa		+					1	1-2
Eragrostis lehmanniana			+				+	2
Other companion species								
Asparagus suaveolens	r	+	+	+	1	+		2
Tragus berteronianus	+	+	+	+		+	1	2
Aristida curvata	+	r	+		+	1		1-2
Asparagus laricinus				+	+	+		2
Stipagrostis obtusa				+	+			2
Sarcocaulon patersonii				+	+			1-2
Pteronia mucronata					+	+		2
Talinum caffrum	+		+					1-2
Chloris virgata			+				+	1-2

further occurring in relevé 353: *Rhigozum trichotomum* (2b), *Pteronia sordida* (+), *Zygophyllum gilfillani* (+), *Eragrostis porosa* (+), *Nycteranthus noctiflorus* (+), *Drosanthemum floribundum* (+); relevé 398: *Aptosimum spinescens* (+); relevé 365: *Eberlanzia spinosa* (+), *Osteospermum spinescens* (+), *Aloe claviflora* (+); relevé 367: *Osteospermum spinescens* (+), *Pteronia acuminata* (+); relevé 369: *Acacia mellifera* subsp. *detinens* (+), *Aptosimum marlothii* (1), *Limeum aethiopicum* (+), *Polygala leptophylla* (+), *Monechma incanum* (1), *Blepharis capensis* (+), *Selago albida* (+), *Tragus koelerioides* (+), *Caralluma lutea* (+), *Indigofera alternans* (+), *Stipagrostis ciliata* (+); relevé 370: *Pteronia punctata* (+); relevé 413: *Eragrostis bicolor* (1).

0,05 m in height, is always extremely sparse. Following FOSBERG's (1967) system, the *Lycium prunus-spinosa* Community belongs to formations 2E2.4, deciduous thorn shrub steppe savanna, or 3B2.2, deciduous desert thorn scrub. It is possible that the *Lycium prunus-spinosa* Community belongs to the Pentzietea incanae.

As pointed out in Chapter II.4, several pans occur in the area downstream of Petrusville. These pans, when not bare, carry a vegetation which is often considerably different from the surrounding vegetation. From the southern Kalahari LEISTNER & WERGER (1973) described several associations occurring on pan floors. These associations have, however, not been found in the Upper Orange River area. In the vicinity of Petrusville the vegetation of a calcrete pan was sampled (table VI.7.5). It consists of what might be called the *Eragrostis truncata-Titanopsis schwantesii* Community, which possibly belongs to the Pentzietea incanae. It is a unistratal vegetation of very low dwarf shrubs, succulents and grasses, up to 0,08 m high, covering approximately 65 per cent. In FOSBERG's (1967) classification this community belongs to formation 2C1.3, evergreen narrow sclerophyll dwarf steppe scrub.

TABLE VI.7.5 ERAGROSTIS TRUNCATA-TITANOPSIS SCHWANTESII COMMUNITY

Relevé no.	387
SL	29° 53'
EL	24° 40'
Total cover (%)	65
Total no. of species	12
Eragrostis truncata	4.3
Titanopsis schwantesii	1.2
Polygala pungens	+.2
Hermannia pulverata	+.2
Thesium hystrix	+.2
Pentzia calcarea	+.2
Gnidia polycephala	r
Plinthus karooicus	+.2
Asparagus suaveolens	+.2
Enneapogon brachystachyus	r
Lycium salinicolum	+.2
Nolletia ciliaris	+.1

VII. ECOLOGICAL OUTLINE AND CONCLUDING REMARKS

The overriding feature in the Upper Orange River area, as apparent from the physiographic description in Chapter II, is the more or less east-west gradient following the rivercourse. This gradient is a result of parallel changes in altitude, from nearly 1 400 m in the east to just below 1 000 m in the west of the study area; in climate, from warm temperate and relatively humid near Lesotho to a hot and dry steppe or semi-desert climate near Douglas; in geology, from the Upper Karoo strata emerging near Sterkspruit to the Lowest Karoo strata and ancient Ventersdorp lava emerging in the section between Hopetown and the Orange-Vaal confluence; in geomorphology, from the strongly dissected country upstream of Aliwal North to the monotonous flat landscape downstream of Petrusville; and in soils, from the Highveld prairie soils on the eastern plateau to the aeolian Kalahari sands in the westernmost part of the Upper Orange River area. Such a change in all physiographic factors necessarily implies a change in general ecology along the gradient, which can be expected to find its expression in the communities in the area. The changes in general ecology or habitat features can be expressed in a community both in the constituent species and their autecology as well as in community structure.

In studying the expression of changing habitats of the various communities in the species composition and structure of the communities in the Upper Orange River area, a second factor should be taken into account. This is the situation in the landscape, as a result of which the moisture regime of the soil is basically different (cf. BATANOUNY & SHEIKH, 1972). As a result of different situations in the landscape three major types of habitat can be distinguished:-

(1) The deep sandy levees along the river, which store probably a large amount of water and bear a riverine forest and woodland vegetation.
(2) The slopes which have shallow, well-drained, rocky lithosols and bear mainly a shrubby vegetation.
(3) The flats with usually deep soils of sandy loam or loamy sand, or wind-blown Kalahari sand, which bear mainly a grass and dwarf shrub vegetation.

These three different major types of habitat correspond to three major habitat-vegetation complexes, namely the riverine forest and woodland vegetation, the shrubby vegetation of the slopes and the non-shrubby vegetation of the flats. Few exceptions have to be accounted for, such as the Pentzio calcareae-Stipagrostietum acacietosum giraffae occurring on flats with deep well-drained Kalahari sand which should be included in the group "shrubby vegetation of the slopes". The *Brachiaria serrata-Elyonurus argenteus* Community should be included in the group "non-shrubby vegetation of the flats" although this community, in exceptional cases, occurs on fairly steep south facing slopes. The Monechmatetum incani occurs in shrubby as well as in non-shrubby phases, so should each be included in two groups.

The various communities making up these three major habitat-vegetation complexes can be arranged according to their habitat in three parallel series from mesic to xeric in correspondence with the climatic gradient of the study area in particular. Neglecting

TABLE VII.1 COMMUNITIES ARRANGED ALONG THE MESIC-XERIC GRADIENT

	Riverine forest and woodland		Shrubby vegetation of the slopes	
	communities	main structural types	communities	struc
	Rhoo-Diospyretum celtidetosum	deciduous forest	Rhamno-Roetum	everg scrub decid scrub
mesic			Mayteno polyac.-Oleetum afr. typicum Rhoo-Aloetum ferocis Blepharido-Rhoetum	everg everg fores stepp
	Rhoo-Diospyretum acacietosum kar.	deciduous forest	Mayteno polyac.-Oleetum afr. chamareetosum Setario lind.-Buddleietum sal.	everg scrub stepp
			Stachyo-Rhoetum Nanantho vitt.-Rhoetum	everg scrub stepp
	Zizipho-Acacietum karroo	deciduous forest	Zizipho-Rhigozetum obovati	decid scrub stepp
			Pentzio calc.-Stipagrostietum acacietosum gir.	everg savan
			Melhanio rehm.-Hermannietum spin. Monechmatetum incani Nestlero hum.-Pteronietum sord. stipagrostietosum cil.	decid scrub shrub
xerix			Eriocephalo-Eberlanzietum	decid stepp decid scrub

	Non-shrubby vegetation of the flats	
types	communities	main structural types
/deciduous evergreen/ steppe	Brachiaria ser.-Elyonurus arg. Eragrostis plana-Eragr. gumm.	seasonal short grass
forest to steppe evergreen rub	Pentzia glob.-Eragrostis curv.	open evergreen dwarf scrub with closed ground cover
steppe rgreen vanna		
steppe rgreen vanna	Hermannio coc.-Nestleretum conf. Osteospermetum leptolobi	evergreen dwarf steppe scrub/evergreen dwarf shrub steppe savanna
steppe iduous vanna		
steppe	Enneapogono br.-Stipagrostietum Pentzio calc.-Stipagrostietum typicum	evergreen dwarf shrub steppe savanna
steppe iduous ppe savanna	Monechmatetum incani Nestlero hum.-Pteronietum sord. typicum	evergreen dwarf steppe scrub
shrub vanna/ desert		

the minor communities described in Chapters VI.1 and VI.7, the series as listed in table VII.1 are thus obtained.
The shift in habitat of the various communities is as far as species composition is concerned in the first place expected to be reflected in the character and differential species, because these are species whose ecological amplitudes restrict them to specific habitats in the study area. The autecology of the character and differential species is particularly important in this respect, although a detailed knowledge of the autecology of each of these species does not necessarily result in a detailed knowledge of the ecology of the community, which they constitute (ODUM, 1959; WESTHOFF, 1969). However, virtually no autecological information on the species occurring in the Upper Orange River area is available, but it is possible to assess a species on its general appearance as more or less mesophytic or xerophytic.

In the riverine forest and woodland vegetation the general climatic gradient from mesic to xeric is reflected in the leaves of the tree layer (compare Chapter VI.1). In the most mesic part of the study area *Celtis africana* forms the tree layer of the Rhoo-Diospyretum celtidetosum. Towards the drier part of the area the Rhoo-Diospyretum acacietosum karroo occurs, with *Acacia karroo* forming the tree layer, and in the driest part of the study area the Zizipho-Acacietum karroo is found, with *Acacia karroo* and *Ziziphus mucronata* as codominants in the tree layer. The lower strata inside the riverine forest do not show the gradient from mesic to xeric, indicating that inside the forest this gradient barely exists. In the Rhoo-Diospyretum the most mesophytic species are *Rubia cordifolia, Cineraria lobata* and *Achyranthes aspera,* while in the Zizipho-Acacietum karroo these are *Setaria verticillata* and *Senecio burchellii.* The other species are all less mesophytic, but they do not contribute to give one of the syntaxa a clearly more xeromorphic physiognomy than any other in the riverine forest and woodland vegetation.
Also, there is no clear change in structure in this vegetation which could have indicated an increase in xeric conditions in the down-river direction.

Thus, although the uppermost layers which are most exposed to the macroclimatic factors causing the gradient from mesic to xeric reflect this change in their leaf types, the moisture regime of the deep sandy levees is apparently favourable to such an extent that it can support a vegetation with the closed structure of a forest. Owing to this closed forest structure of the levee vegetation, the macroclimatic factors have only little impact on the habitat inside the forest. Forest structure allows for the creation of its own internal habitat conditions which stay largely similar over its entire range. Therefore mesophytic plants occur in more or less similar quantities in all syntaxa of the riverine forest and woodland vegetation. It may thus be concluded that in this vegetation the moisture regime of the substrate is the strongest and most decisive environmental factor and not the complex of macroclimatic factors. In this sense the riverine forest and woodland represents an azonal vegetation type (WALTER, 1954a). In accordance with this status of azonal vegetation type, the riverine forest and woodland is not divided by phytogeographical boundaries (compare Chapter III). Apart from a relatively large amount of apo- and neophytes, it shows over its entire range in the study area strong palaeotropic affinities, while no subdivisions present in the surrounding area, divide the riverine vegetation.

In the mesic to xeric series of the shrubby vegetation of the slopes in the study area fourteen syntaxa are involved. The most mesic is the Rhamno-Rhoetum, occurring on the south facing slopes in the area east of Aliwal North. The Rhamno-Rhoetum counts a considerable number of mesophytes among its character and differential species and also species of a temperate humid distribution are common in this group (compare Chapters, III and VI.4).

Next in the series follow the other two Grewio-Rhoetalia erosae associations, the Rhoo-Aloetum ferocis and the Blepharido-Rhoetum, together with the Mayteno polyacanthae-Oleetum africanae typicum. These syntaxa occur either on north facing slopes in the warm temperate, relatively humid area upstream of Aliwal North, or on south facing slopes or sheltered sites in the slightly drier area between Aliwal North and Colesberg (compare Chapter VI.4). The number of mesophytes in these communities has decreased markedly in comparison to the Rhamno-Rhoetum, but there are still mesophytes present, like *Senecio hieracioides* and particularly species in the order character and differential group of the Grewio-Rhoetalia erosae, such as *Melica decumbens*, *Ehrharta erecta*, *Berkheya discolor* and *Polygala amatymbica*. Others like *Rhynchelytrum repens*, *Aristida bipartita*, *Pavonia burchellii* and also *Grewia occidentalis* and *Celtis africana* apparently indicate relatively mesic conditions in the study area. At the same time the number of xeromorphic species increases in the above-mentioned communities, while in the Rhoo-Aloetum ferocis succulents become significant. They possibly indicate the importance of hot and relatively dry conditions of its habitat during the day time, when the sun radiation constitutes a salient environmental factor on these north facing slopes.

The next link in the series is formed by the Mayteno polyacanthae-Oleetum africanae chamareetosum and the Setario lindenbergianae-Buddleietum salignae. The former community occurs on less sheltered but still not strongly xeric sites in the area between Aliwal North and Colesberg, and the latter community on southerly or westerly facing slopes just below the summits of the mountains in the area downstream of Colesberg until the vicinity of Petrusville where it constitutes the least xeric habitat. The Mayteno polycanthae-Oleetum africanae chamareetosum possesses apart from *Senecio hieracioides* no real mesophytes, although species like *Pelargonium aridum*, *Mohria caffrorum*, and a few others do not occur on hot and dry sites. In the Setario lindenbergianae-Buddleietum salignae only *Solanum retroflexum* can be regarded as relatively mesophytic and the relatively xeromorphic species like *Buddleia saligna*, *Osyris lanceolata*, *Asparagus striatus* and *Cussonia paniculata* are significant in this association (compare Chapter VI.4).

Next in the series are the Stachyo-Rhoetum and the Nanantho vittati-Rhoetum, both mainly occurring on northerly facing slopes in the False Upper Karoo between Aliwal North and Petrusville. No real mesophytes are found in these associations and succulents and species with coriaceous, sclerophyllous and small leaves become important (compare Chapter VI.4).

The Zizipho-Rhigozetum obovati represents the next link. It occurs on hot, dry sites in the narrow valley trough downstream from Skurwekop and on the slopes of inselbergs on the flats west of Petrusville. Several species in this association occur more commonly in the False Upper Karoo and reach their most westward distribution into the arid zone here (compare Chapter VI.5). Most species have small, hairy or coriaceous to sclerophyllous leaves and succulents are not rare.

The penultimate link in the series is formed by the Pentzio calcareae-Stipagrostietum acacietosum giraffae which occurs on deep Kalahari sand. The sand probably stores in its lower layers a considerable amount of water which is available for the trees and shrubs with deep root systems. These species, *Acacia giraffae* and *Acacia tortilis* subsp. *heteracantha*, possess microphyllous, slightly coriaceous leaves. The dwarf shrubs in this community are clearly xeromorphic, however, and grassess, which are only physiologically active during the short rainy season and whose aerial parts die away soon afterwards, are the most prominent species (compare Chapter VI.6).

In the Upper Orange River area the end link in the series from mesic to xeric is formed by the Melhanio rehmannii-Hermannietum spinosae, the Monechmatetum incani, the Nestlero humilis-Pteronietum sordidae stipagrostietosum ciliatae and the Eriocephalo-Eberlanzietum, all occurring downstream of Petrusville and mainly west of Hopetown. The species of all these communities show rather strong xeromorphic features, such as small, hairy and sclerophyllous leaves, strong spinosity, and succulence. Good examples are *Hermannia spinosa, Lasiocorys capensis, Blepharis mitrata, Barleria lichtensteiniana, Mestoklema tuberosum, Hoodia gordonii, Monechma incanum, Nestlera humilis forma, Pteronia sordida, Microloma massonii, Zygophyllum gilfillani, Eberlanzia spinosa, Aptosimum spinescens* (compare Chapter VI.5).

The gradient from mesic to xeric is thus clearly reflected in the species composition of the various shrubby communities of the slopes.

The gradient from mesic to xerix is also expressed in the structure of these various shrub communities although less marked than in the species composition. The series start with an evergreen to deciduous scrub or steppe scrub, followed by an evergreen forest or steppe forest formed by the Mayteno polyacanthae-Oleetum africanae typicum. The difference between the scrub and forest formations is just a matter of height. The next stage is an evergreen steppe scrub or evergreen steppe savanna, as represented by several Rhoetea erosae communities. Then follow the Pentzietea incanae communities as deciduous steppe scrub, deciduous shrub savanna or deciduous shrub steppe savanna, interrupted by the evergreen steppe savanna formed by the Pentzio calcareae-Stipagrostietum acacietosum giraffae, on deep Kalahari sand. The series is closed by the deciduous shrub steppe savanna or deciduous desert scrub formed by the Eriocephalo-Eberlanzietum. Thus a clear but inconspicuous gradient is shown from evergreen fairly dense vegetation to deciduous open vegetation.

The position of each community in this series is not simply determined by its distribution from east to west in the study area, and thus by macroclimatic factors alone, but as has been shown, is strongly influenced by the slope direction and sometimes by soil type and relative altitude. Hence, geological and geomorphic characteristics are indirectly involved. These characteristics together with the macroclimatic changes in the east-west direction, determine the relative position of the shrubby communities in the mesic-xeric gradient.

The shrubby communities show a clear phytogeographic subdivision. The Grewio-Rhoetalia erosae, occurring east of Bethulie, and in particular the Rhamno-Rhoetum, although basically Sudano-Zambesian in their floristical affinities, contain a considerable number of taxa with an Afro-montane and an Afro-montane-Cape distribution (compare Chapters III and VI.4). The remaining Rhoetea erosae communities are all clearly Sudano-Zambesian, although Karoo-Namib taxa and particularly species with a central type of distribution also occur. The Pentzietea incanae and the Pentzio calcareae-Stipagrostietum acacietosum giraffae, which belongs to the Stipagrostion, belong chorologically to the Karoo-Namib Region, but Sudano-Zambesian and centrally distributed taxa reach different degrees of importance in the various communities. In the Zizipho-Rhigozetum obovati these elements are of considerable importance, whereas they are virtually lacking in the Zygophyllion gilfillani and the Eriocephalo-Eberlanzietum. The Capensis element is negligible in all these shrubby communities (compare Chapters III, VI.4, VI.5 and VI.6).

In the non-shrubby communities of the study area the series from mesic to xeric start with the *Brachiaria serrata-Elyonurus argenteus* and the *Eragrostis plana-Eragrostis gummiflua* grassland Communities. Mesophytes and species widely distributed in the warm temperate humid zone commonly occur in these communities, for example *Eragrostis racemosa*, *Eragrostis capensis*, *Ajuga ophrydis*, and others (compare Chapter VI.2).

The *Pentzia globosa-Eragrostis curvula* Community comes next in the series. Although grassess still form the most conspicuous component in this community, karroid dwarf shrubs with small ericoid leaves start to play an important role as well (compare Chapter VI.2).

Then follow the dwarf shrub communities on loamy soils, the Hermannio coccocarpae-Nestleretum confertae and the Osteospermetum leptolobi, both occurring mainly between Aliwal North and Colesberg. In these associations the conditions of their habitats is well indicated by the xeromorphy of the karroid dwarf shrub species, which constitute the dominant growth form (compare Chapter VI.3-4).

The next link in the series is formed by the Stipagrostion communities of the Kalahari sand, the Enneapogono brachystachyi-Stipagrostietum and the Pentzio calcareae-Stipagrostietum typicum. In these communities the karroid dwarf shrubs and the low xeromorphic deciduous shrub *Rhigozum trichotomum* are well represented, but the dominant growth form is constituted by grasses with a short physiologically active period during the rainy season and whose aerial parts are soon afterwards dead. Examples are *Enneapogon brachystachyus*, *Stipagrostis obtusa* and *Stipagrostis ciliata* (compare Chapter VI.6).

The series is closed in the study area by the Monechmatetum incani and the Nestlero humilis-Pteronietum sordidae typicum. In these open communities dwarf shrub species often spinous, with small, hairy or sclerophyllous leaves are again the most important constituents (compare Chapter VI.5).

The gradual shift from rather mesic to xeric conditions of the habitat is thus well reflected in the species composition of the non-shrubby communities.

The shift in habitats of the various communities is also shown in their structure, although again less marked than in their species composition. At the mesic beginning of the series, the vegetation consists of seasonal short grass, followed by open evergreen dwarf scrub with closed ground cover as represented by the *Pentzia globosa-Eragrostis curvula* Community. Then follow the False Upper Karoo communities as evergreen dwarf steppe scrub or evergreen dwarf steppe savanna. These formations are also formed by the more xeric Stipagrostion and Pentzietea incanae communities. The non-shrubby communities thus represent structurally a series from closed herby vegetation to open dwarf steppe scrub, in which grasses are successively less prominent.

As in the series of the shrubby communities, the position in the mesic-xeric series of these non-shrubby communities is again not simply determined by their distribution in east-west direction in the study area, which would mean solely by macroclimatic factors. Soil type can be a principal factor too, as is shown in the case of the Stipagrostion communities.

Phytogeographically these communities can again be subdivided meaningfully. The grassland communities occurring east of Aliwal North are real Sudano-Zambesian in their floristic affinities. The Hermannio coccocarpae-Nestleretum confertae and the Osteospermetum leptolobi, occurring downstream of these grassland communities, are also Sudano-Zambesian, but the Karoo-Namib element gradually increases in importance and taxa with a central type of distribution are numerous. The Stipagrostion and Pentzietea incanae communities of the non-shrubby series, occurring downstream of the escarpment near Petrusville, are real Karoo-Namib in their affinities. The Sudano-Zambesian element does not constitute a significant fraction here, while centrally distributed taxa are well represented. Capensis affinities with any of the communities of this series are again negligible (compare Chapters III and VI).

From the pattern of phytogeographical boundaries through the shrubby communities as well as through the non-shrubby communities it is evident, that several boundaries of ACOCKS' (1953) veld types coincide with chorological boundaries, suggesting that veld types are phytogeographically meaningful.

Because the theory of approach and concepts and the methods applied in the present study have been amply discussed in Chapters IV and V and need not be enlarged on here, only the question of the degree in which anthropogenic influences have determined the structure and floristic composition of the communities in the Upper Orange River area, requires a brief discussion.

No pertinent field work on this subject was carried out during the present survey but field observation and study of relevant literature as discussed in Chapter II.6 allow some general conclusions. The floristically rich shrubby communities, which generally occur on the steeper slopes and are therefore not so easily accessible to sheep, are clearly least affected by the now more than one century long continuous severe overgrazing. Most affected seem to be the Pentzio-Chrysocomion and the Stipagrostion communities. These communities are floristically rather poor, and are dominated over extensive areas by a single species: the Pentzio-Chrysocomion by the unpalatable *Chrysocoma tenuifolia* and the Stipagrostion often by the mostly defoliated shrub *Rhigozum trichotomum*. The Pentzietea incanae are frequently dominated by the shrub *Acacia mellifera* subsp. *detinens* and the eastern grassland communities by *Euryops annae*, both also as a result of overgrazing.

The Pentzio-Chrysocomion, and the Stipagrostion in their *Rhigozum*-phases, represent typical convergent communities in a relation theory terminology (VAN LEEUWEN, 1966, 1970). According to the third basic relation of this theory the spatial monotony of these communities implies a temporal instability. This is well demonstrated by the change in species composition occurring in these communities when they are protected from severe grazing for a few seasons (compare Chapter II.6). Within the study area the communities of the steep slopes, which are nearly inaccessible to sheep, such as the Enneapogono scabri-Rhigozion obovati, and particularly the Indigofero spinescentis-Rhoion erosae communities, represent on the other hand divergent communities. The spatial diversity in these communities implies according to the same third basic relation of the relation theory a stability in time. The fact that these communities, particularly those belonging to the Indigofero spinescentis-Rhoion erosae, have presumably not changed in species compostion to any important degree since the introduction of merino sheep, demonstrates this point.

A brief remark finally on a result, which although connected with the present study cannot be concluded directly from the facts outlined above. The success of the Zürich-Montpellier approach in providing required information at an appropriate level of detail on the vegetation and ecology of several South African biomes, as demonstrated by various smaller surveys (see Chapter V) and particularly by the present one, has resulted in a wide interest of South African ecologists in this approach. There are signs at present that this interest will lead to the compilation of a badly needed, suitable multi-purpose classification of the South African vegetation, based on Zürich-Montpellier concepts and methodology.

SUMMARY

An account is given of the syntaxonomy and synecology of the vegetation of the Upper Orange River, South Africa. The study area is 656 km long, varying in width and measuring just over 3 000 km^2 in area. It covers grassland, open dwarf shrub and shrubby vegetation.

In Chapter I it is pointed out that the study was initiated as a result of the huge waterworks under construction along the Orange River, which will bring about considerable changes in due course.

Chapter II discusses in some detail the physiographical factors of the area as well as human impact on the vegetation. Some historical notes concerning the study area are made.

The gradient of the river fluctuates somewhat from place to place, but is 0,65 m/km on the average. The study area falls entirely in the regime of a summer rainfall climate, with a maximum precipitation during March and a minimum during June or July. Precipitation is mostly in the form of thunderstorms. The sunshine in the entire area is between 70 and 80 per cent of the possible annual amount. The dominant wind direction for the area is between N and NW. There are considerable diurnal changes in most meteorological factors. Frost and snowfall can occur over the entire area, the latter rather infrequently, and both more often in the eastern than in the western part. It is emphasized that there is a major, complex gradient following the river course. In meteorological factors there is a decreasing gradient in average annual relative humidity and in precipitation, which changes from over 600 mm in the east to less than 300 mm in the west, while there is an increasing gradient in temperature, particularly so in the average daily maxima of the warmest month, in cloudiness, in evaporation and in mean saturation deficit. This results in a gradient of climates from relatively humid, temperate tropical in the east, over a drier steppe climate to a dry sub-desert climate in the west. Due to topographical differences, which are more prominent in the east than in the west, there are considerable differences in meso- and microclimates within the study area.

In the east-west direction the river flows over successively older strata of the Karoo System, first of the Stormberg Series, then of the Beaufort and Ecca Series and finally of the Dwyka Series which are locally interrupted by the Precambrian Ventersdorp lavas. The succession is frequently interrupted by dolerite intrusions. Tertiary to recent aeolian Kalahari sand and calcrete accumulations occur in the westernmost part of the study area, while alluvial deposits occur locally all along the river course.

Also geomorphologically the landscape changes from a rather dissected countryside in the east to the flat monotonous landscape with isolated inselbergs and scattered pans in the west.

Soils in the study area vary from the Highveld Prairie soils in the east, over the Solonetzic soils to the sandy and calcareous desert soils in the west. Shallow lithosols are common throughout the study area.

In the vegetation a gradient from grassland over open dwarfshrub and grass vegetation

to an open dwarf shrub steppe is covered by the study area in an east-west direction. Slopes are usually covered by an open shrubby vegetation, while on Kalahari sand in the western part of the study area an open tree savanna locally occurs. A riverine forest and woodland vegetation fringes the river over virtually the entire study area.

Land use in the study area is mainly mixed farming in the east and extensive stock farming in the west.

In Chapter III phytogeographic literature concerning the study area is briefly reviewed. It is pointed out that a major chorological boundary runs through the area, namely the boundary between the Sudano-Zambesian Region and the Karoo-Namib Region, which traverses the valley just downstream of Petrusville, coinciding with the boundary between dissected and flat countryside. In the easternmost part of the area the Afro-montane element is well represented. The Cape element is virtually lacking in the entire Upper Orange River valley. An enumeration of some species occurring in the area with Afro-montane, Afro-montane-Cape, Capensis, Sudano-Zambesian, Karoo-Namib and "Central" distribution patterns is given. Also some species with distribution patterns not exemplifying this chorological classification of the area are listed.

In Chapter IV various approaches to the study of vegetation are outlined and the place of the Zürich-Montpellier approach is discussed. It is pointed out that, whereas formerly rivalry between the various Schools was one of the most striking features in vegetation science, the further development of techniques and the more solid definition of concepts has led more and more to a mutual understanding between workers of the various approaches. The significance of the Zürich-Montpellier approach in the study of vegetation is accentuated by emphasizing its scientific soundness, its efficiency and versatility and the fact that it provides a classification at an appropriate level.

Concepts and methods as in use in the Zürich-Montpellier School are elucidated in Chapter V. The analytic or sampling phase and the synthetic phase in a vegetation study are discussed in detail and it is indicated in what way concepts and methods have been applied in the present study. At the end of Chapter V a theoretical definition of the study area is given and it is pointed out how this definition was interpreted in practice.

A description of the plant communities, their structure, habitat, distribution within the study area and syntaxonomical rank is given in Chapter VI. All syntaxa are newly described. The riverine forest and woodland vegetation covering the levees of the Upper Orange River is described in two associations, the Rhoo-Diospyretum and the Zizipho-Acacietum karroo, belonging to the same alliance, the Diospyrion lycioidis. The Rhoo-Diospyretum is divided into two subassociations, the celtidetosum and the acacietosum karroo, and also an *Acacia karroo* variant of the celtidetosum is recognized. These syntaxa occur in a geographical sequence, probably due to the climate gradient in the area. Some riverine communities of minor extent and importance are also briefly described. Three communities are distinguished in the grassland vegetation of the eastern part of the study area but they are not ranked syntaxonomically.

One association, the Hermannio coccocarpae-Nestleretum confertae, with three subassociations, the aptosimetosum marlothii, the eragrostietosum curvulae and the oropetietosum, as well as a variant with *Eragrostis lehmanniana* are described from the dwarf shrub vegetation of the plains of the False Upper Karoo and their differences in habitat is indicated. A provisional description is given of the alliance Pentzio-Chrysocomion, to which this association belongs.

The shrubby communities of the slopes in the eastern grassland area and the False Upper Karoo all belong to the class Rhoetea erosae in which two orders have been recognized. The Grewio-Rhoetalia erosae occur on mesic sites, mainly in the area east of Aliwal North, and comprise three associations: the Rhamno-Rhoetum on southerly facing slopes, the Rhoo-Aloetum ferocis on northerly facing slopes and the Blepharido-Rhoetum on mesic sites near Aliwal North. The first two associations are combined into the alliance Indigofero spinescentis-Rhoion erosae. The Afro-montane and the Afro-montane-Cape elements are well represented in the Grewio-Rhoetalia erosae, particularly in the Rhamno-Rhoetum. The Rhoetalia ciliato-erosae comprise most of the shrubby communities between Aliwal North and Petrusville and include five associations: the Osteospermetum leptolobi on gentle sloping terrain with shallow soils on sandstones and mudstones, with the subassociations typicum and aptosimetosum marlothii; the Stachyo-Rhoetum, mainly on northerly facing dolerite slopes, with the subassociations polygaletosum and hermannietosum candidissimae and, near Petrusville, a variant with *Salvia namaensis*; the Nanantho vittati-Rhoetum, mainly on northerly facing sandstone slopes near Bethulie; the Mayteno polyacanthae-Oleetum africanae, largely confined to steep southerly facing dolerite slopes, with the subassociations typicum and chamareetosum; and the Setario lindenbergianae-Buddleietum salignae on dolerite slopes just below the summits in the area around Petrusville. The first three associations are combined into the alliance Hibisco marlothiani-Rhoion erosae. The western boundary of the Rhoetea erosae coincides in the study area with the boundary between the Sudano-Zambesian and Karoo-Namib Regions.

The shrub and dwarf shrub communities on rocky soils downstream of Petrusville belong largely to the class Pentzietea incanae comprising five associations: the Zizipho-Rhigozetum obovati, mainly on dolerite slopes between Skurwekop and Hopetown, with the subassociations cheilanthetosum ecklonianae and inops; the Melhanio rehmannii-Hermannietum spinosae on andesitic lava slopes downstream of Hopetown; the Monechmatetum incani on alkaline sites where some concentration of run-off occurs, with the subassociations typicum and pentzietosum calcareae; the Nestlero humilis-Pteronietum sordidae on calcrete rich substrates downstream of Orania, with the subassociations typicum and stipagrostietosum ciliateae; and the Eriocephalo-Eberlanzietum on nearly level, slightly acid, loamy sands between Skurwekop and Hopetown. The Zizipho-Rhigozetum obovati and the Melhanio rehmannii-Hermannietum spinosae are combined into the alliance Enneapogono scabri-Rhigozion obovati; the Monechmatetum incani and the Nestlero humilis-Pteronietum sordidae into the Zygophyllion gilfillani. Both alliances are combined into the order Pentzio incanae-Rhigozetalia trichotomi.

Two associations occur in the study area on Kalahari sand: the Enneapogono brachystachyi-Stipagrostietum on slightly loamy sand, and the Pentzio calcareae-Stipagrostietum on pure Kalahari sand overlying calcrete. The latter association comprises the subassociations typicum and acacietosum giraffae. Both associations, together with some associations described from the southern Kalahari, can be combined into the alliance Stipagrostion which is described provisionally.

Some communities of minor extent in the study area are briefly described at the end of Chapter VI, without attempting to rank them syntaxonomically.

In Chapter VII an integrated outline of the ecological and syntaxonomical gradient in the study area is given, emphasizing on climatic changes and floristic and structural features in the communities. Based on the moisture regime of the soil, three parallel series of communities from mesic to xeric are represented and the expression of habitat conditions in species composition and community structure is discussed. Finally brief remarks are made on the relation between the impact of mismanagement of the vegetation and diversity in landscape and vegetation.

A check list of species occurring in the relevés is appended as well as an index to genera and families.

OPSOMMING

Die studie handel oor 'n sintaksonomiese en sinekologiese ondersoek van die plantegroei van die dal van die Bo-Oranjerivier in Suid-Afrika. Die ondersoekgebied is 656 km lank, varieer in breedte en beslaan ietwat meer as 3 000 km^2. Dit sluit grasveld-, dwergstruik- en struikagtige plantegroei in.

In hoofstuk I word verduidelik dat die ondersoek onderneem is na aanleiding van die enorme waterwerke wat in die Oranjeriviergebied in aanbou is en wat binne afsienbare tyd aansienlike veranderings teweeg sal bring.

Die fisiografiese faktore in die ondersoekgebied en die invloed van menslike aktiwiteit op die plantegroei word in hoofstuk II bespreek. Die hoofstuk bevat ook enkele geskiedkundige besonderhede wat betrekking op die gebied het. Die gradient van die rivier wissel in 'n mate van plek tot plek, maar is gemiddeld 0,65 m/km. Die ondersoekgebied val geheel en al in die somerreënvalstreek. Maart is die maand met die maksimum neerslag en die minimum is in die maande Junie en Julie. Die neerslag is gewoonlik in die vorm van donderbuie. Die sonskyn is oor die hele gebied tussen 70 en 80 persent van die moontlike jaarlikse totaal en die oorheersende windrigting is tussen N en NW. Daar is aansienlike verskille in die meerderheid meteorologiese faktore binne 'n etmaal. Oor die hele gebied kan ryp en af en toe ook sneeu voorkom, hoewel dit meer algemeen in die oostelike as in die westelike deel is. Nadruk word gelê op die belangrike, komplekse gradient wat daar van oos na wes heers. Wat die meteorologiese faktore betref, is daar 'n afnemende gradient in gemiddelde jaarlikse relatiewe lugvogtigheid en in neerslag, wat verskil van meer as 600 mm in die ooste tot minder as 300 mm in die weste van die ondersoekgebied. 'n Toenemende gradient in temperatuur veral wat die gemiddelde daaglikse maksima vir die warmste maand betref, in wolkbedekking, in verdamping en in gemiddelde versadigingstekort kom ook in die gebied voor. Daar is dus 'n klimaatsgradient wat wissel van relatief vogtig gematig-tropies in die ooste, deur 'n droër steppeklimaat tot 'n droë woestynagtige klimaat in die weste. As gevolg van verskille in topografie, wat in die ooste meer prominent is as in die weste, is daar aansienlike verskille in meso- en mikroklimaat binne die ondersoekgebied.

In die oos-wes rigting stroom die rivier oor opeenvolgende ouer afsettings van die Karoo Sisteem, naamlik eerstens van die Stormbergserie, daarna van die Beaufort- en Eccaserie en uiteindelik van die Dwykaserie, wat plek-plek deur Prekambriese Ventersdorp lawa-afsettings onderbreek word. In al die afsettings kom daar dikwels dolerietindringings voor. Tersiêre en resente eoliese afsettings van Kalaharisand en kalkkreet kom in die westelike deel van die ondersoekgebied voor, en alluviale afsettings word plek-plek langs die hele rivier aangetref. Geomorfologies verander die landskap van taamlik gebroke in die oostelike dele tot plat eentonig met alleenstaande koppies en verspreide panne in die weste.

Binne die ondersoekgebied verskil die gronde van die Hoëveldse prairiegronde in die ooste, oor die solonetsgronde tot die sanderige en kalkryke woestyngronde in die weste. Vlak litosols kom algemeen voor. Die plantegroei wissel van oos na wes van grasveld, oor oop dwergstruik en grasse tot 'n oop dwergstruiksteppe. Die hange is gewoonlik

begroei met 'n oop struikagtige plantegroeitipe en op die Kalaharisand in die westelike deel van die ondersoekgebied kom daar hier en daar 'n oop boomsavanne voor. Oor byna die hele ondersoekgebied groei daar 'n stroomoewerbos langs die rivier.

Bodembenutting binne die ondersoekgebied verskil van hoofsaaklik gemengde boerdery in die ooste tot ekstensiewe veeboerdery in die weste.

Die fitogeografiese literatuur, wat op die ondersoekgebied betrekking het, word in hoofstuk III kortliks bespreek. 'n Belangrike fitogeografiese grens, naamlik dié tussen die Sudano-Sambesiese en die Karoo-Namib-regio's kruis die ondersoekgebied net onderkant Petrusville. Hierdie grens val saam met die grens tussen die gebroke en die plat landskappe. In die mees oostelike deel van die ondersoekgebied is die Afromontane element goed verteenwoordig, terwyl die Kaapse element vrywel geheel en al ontbreek in die hele Bo-Oranjegebied. Daar word 'n lys gegee van soorte wat binne die ondersoekgebied voorkom en wat Afro-montane, Afro-montaan-Kaapse, Kaapse, Sudano-Sambesiese, Karoo-Namib- en "Sentrale" verspreidingspatrone vertoon. Daar word ook 'n lys van soorte gegee waarvan die verspreidingspatrone nie as voorbeelde vir hierdie plantegeografiese klassifikasie kan dien nie.

In hoofstuk IV word die verskillende benaderings tot die bestudering van plantegroei geskets en die plek wat die benadering van die Zürich-Montpellier Skool hierby inneem word bespreek. Dit blyk dat, terwyl vroeër wedywering tussen die verskillende Skole één van die opvallendste verskynsels in die plantekologie was, die ontwikkeling van nuwe tegnieke en die verbeterde definiëring van begrippe geleidelik gevoer het tot 'n beter wedersydse begrip tussen die aanhangers van die verskillende Skole. Daar word veral klem gelê op die belangrike plek wat die Zürich-Montpellier benadering inneem in die bestudering van plantegroei deur daarop te wys dat dit 'n wetenskappelik bevredigende, doeltreffende benadering is, wat 'n oop klassifikasie op 'n gewenste vlak van gedetailleerdheid lewer.

Die begrippe en metodes soos gebruik deur die Zürich-Montpellier Skool en soos toegepas in hierdie ondersoek, word in hoofstuk V verduidelik. Die analitiese fase, wat die monsterneming behels, en die sintetiese fase van die plantegroeistudie word in besonderhede bespreek. Aan die einde van hoofstuk V word die ondersoekgebied teoreties gedefinieer en word aangedui hoe daar van hierdie definisie in die praktyk gebruik gemaak is.

In hoofstuk VI word 'n beskrywing van die plantegemeenskappe, hul struktuur, habitat, verspreiding binne die ondersoekgebied en hul sintaksonomiese rang gegee. Alle sintaksa is nuut beskryf.

Die galerybos, wat op die oewerwalle van die Bo-Oranje groei, word as twee assosiasies beskryf, naamlik die Rhoo-Diospyretum en die Zizipho-Acacietum karroo. Hulle behoort tot dieselfde verbond, die Diospyrion lycioidis. Die Rhoo-Diospyretum is onderverdeel in twee subassosiasies, die celtidetosum en die acacietosum karroo, en binne die celtidetosum word nog 'n variant met *Acacia karroo* onderskei. Hierdie sintaksa kom in 'n geografiese volgorde voor, wat waarskynlik deur die klimaatsgradient binne die gebied veroorsaak word. Enkele rivieroewergemeenskappe wat 'n beperkte verspreiding en belangrikheid het, word ook kortliks beskryf.

In die grasveld van die oostelike deel van die ondersoekgebied is drie gemeenskappe onderskei. Hulle is egter nie in die sintaksonomiese sisteem geplaas nie.

Van die dwergstruikplantegroei van die vlaktes van die Skynkaroo is slegs een assosiasie beskryf, die Hermannio coccocarpae-Nestleretum confertae, met drie subassosiasies, die aptosimetosum marlothii, die eragrostietosum curvulae en die oropetietosum, en 'n variant met *Eragrostis lehmanniana*. Hulle onderlinge habitatsverskille word bespreek. 'n Voorlopige beskrywing van die verbond Pentzio-Chrysocomion, waartoe bogenoemde assosiasie behoort, word gegee.

Die struikagtige plantegroei op die hange in die oostelike grasveldstreek en in die Skynkaroo behoort geheel en al tot die klas Rhoetea erosae, waarbinne twee ordes onderskei word. Die Grewio-Rhoetalia erosae kom op mesiese groeiplekke voor, hoofsaaklik oos van Aliwal-Noord, en omvat drie assosiasies: Die Rhamno-Rhoetum op suidfronthange, die Rhoo-Aloetum ferocis op noordfronthange en die Blepharido-Rhoetum op effens mesiese groeiplekke in die omgewing van Aliwal-Noord. Die eersgenoemde twee assosiasies is in die verbond Indigofero spinescentis-Rhoion erosae verenig. Die Afro-montane en die Afro-montaan-Kaapse elemente is in die Grewio-Rhoetalia erosae goed verteenwoordig, veral in die Rhamno-Rhoetum. Die Rhoetalia ciliato-erosae omvat byna al die struikagtige gemeenskappe in die streek tussen Aliwal-Noord en Petrusville en sluit vyf assosiasies in: Die Osteospermetum leptolobi op effens hellende terrein met vlak gronde op sandsteen en moddersteen, met die subassosiasies typicum en aptosimetosum marlothii; die Stachyo-Rhoetum, wat hoofsaaklik op noordfrontdoleriethange voorkom, met die subassosiasies polygaletosum en hermannietosum candidissimae en, in die omgewing van Petrusville, 'n variant met *Salvia namaensis*; die Nanantho vittati-Rhoetum wat veral op noordfrontsandsteenhange in die nabyheid van Bethulie voorkom; die Mayteno polyacanthae-Oleetum africanae, wat hoofsaaklik beperk is tot steil suidfrontdoleriethange, met die subassosiasies typicum en chamareetosum; en die Setario lindenbergianae-Buddleietum salignae wat in die nabyheid van Petrusville op doleriethange net onderkant die kruine van die berge voorkom. Die eerste drie assosiasies is verenig in die verbond Hibisco marlothiani-Rhoion erosae. Die westelike grens van die Rhoetea erosae val in die ondersoekgebied saam met die grens tussen die Sudano-Sambesiese en Karoo-Namib-regio's.

Die struik- en dwergstruikgemeenskappe op klipperige grond stroomafwaarts van Petrusville behoort hoofsaaklik tot die klas Pentzietea incanae, wat vyf assosiasies insluit: Die Zizipho-Rhigozetum obovati, wat veral op doleriethange in die gebied tussen Skurwekop en Hopetown voorkom, met die subassosiasies cheilanthetosum ecklonianae en inops; die Melhanio rehmannii-Hermannietum spinosae op andesitiese lawahange stroomafwaarts van Hopetown; die Monechmatetum incani op alkaliese plekke waar afloop in 'n mate gekonsentreer is, met die subassosiasies typicum en pentzietosum calcareae; die Nestlero humilis-Pteronietum sordidae op kalkryke substrate stroomafwaarts van Orania, met die subassosiasies typicum en stipagrostietosum ciliatae; en die Eriocephalo-Eberlanzietum op bykans nie-hellende, effens suur, leemsanderige groeiplekke tussen Skurwekop en Hopetown. Die Zizipho-Rhigozetum obovati en die Melhanio rehmannii-Hermannietum spinosae is in die verbond Enneapogono scabri-Rhigozion obovati verenig;

die Monechmatetum incani en die Nestlero humilis-Pteronietum sordidae in die verbond Zygophyllion gilfillani. Beide verbonde is verenig in die orde Pentzio incanae-Rhigozetalia trichotomi.

Binne die ondersoekgebied kom daar twee assosiasies op Kalaharisand voor, die Enneapogono brachystachyi-Stipagrostietum op effens leemerige sandgrond, en die Pentzio calcareae-Stipagrostietum op suiwer Kalaharisand wat oor kalkkreet lê. Die laasgenoemde assosiasie omvat die subassosiasies typicum en acacietosum giraffae. Die twee assosiasies kan met 'n aantal vroeër beskryfde assosiasies, wat in die suidelike Kalahari voorkom, in die verbond Stipagrostion verenig word. Hierdie verbond is voorlopig beskryf.

Enkele gemeenskappe, wat slegs klein oppervlaktes in die ondersoekgebied beslaan, word aan die einde van hoofstuk VI kortliks beskryf maar nie sintaksonomies gerangskik nie.

In hoofstuk VII word daar 'n geintegreerde beeld van die ekologiese en sintaksonomiese gradient in die ondersoekgebied gegee, waarin klem gelê word op die klimaatsveranderinge en die floristiese en strukturele kenmerke van die gemeenskappe. Op die basis van die voghuishouding van die gronde word die gemeenskappe in drie parallele series van mesies tot xeries gerangskik. Die wyse waarop hierdie series die habitatstoestande in soortesamestelling en gemeenskapsstruktuur weerspieël, word bespreek.

Ten slotte word daar enkele kort opmerkings gemaak oor die verband tussen die invloed van wanbestuur van die veld en die diversiteit van die landskap en plantegroei.

'n Lys van soorte wat voorkom in die opnames en 'n indeks van genera met families word in aanhangsels gegee.

SAMENVATTING

De syntaxonomie en synoecologie van de vegetatie van het dal van de Boven-Oranje in Zuid-Afrika worden in dit werk besproken. Het studiegebied is 656 km lang, varieert in breedte en heeft een oppervlakte van iets meer dan 3 000 km^2. Zowel grasland-, open dwergstruik- als struikvegetaties komen in het studiegebied voor.

In hoofdstuk I wordt uiteengezet, dat het onderzoek is ondernomen naar aanleiding van de enorme waterwerken, die er in het gebied van de Boven-Oranje in aanbouw zijn en die er binnen afzienbare tijd belangrijke veranderingen teweeg zullen brengen.

In hoofdstuk II worden de fysiografische factoren, die op het studiegebied betrekking hebben, en de menselijke invloed op de vegetatie besproken. Ook worden er enkele historische feiten betreffende het studiegebied vermeld.

Het verhang van de rivier varieert enigszins van plaats tot plaats, maar is gemiddeld 0,65 m/km. Het studiegebied staat geheel onder invloed van een zomerregenvalklimaat. Maart is de maand met de hoogste neerslag, juni en juli zijn die met de laagste. De neerslag valt gewoonlijk in de vorm van onweersbuien. In het hele gebied bedraagt het aantal uren zonneschijn tussen 70 en 80 percent van het jaarlijks mogelijke aantal. De overheersende windrichting is overal tussen N en NW. Binnen een etmaal zijn er aanzienlijke veranderingen in bijna alle meteorologische factoren te bespeuren. Vorst en sneeuw kunnen overal in het gebied voorkomen, maar zijn zeldzamer in het westelijke dan in het oostelijke deel. Sneeuwval komt niet elk jaar voor. Er wordt nadruk gelegd op de omstandigheid dat het studiegebied in de lengterichting een belangrijke, complexe milieugradiënt vormt. Wat betreft de meteorologische factoren bestaat er een afnemende gradiënt in gemiddelde jaarlijkse relatieve vochtigheid en in neerslag, die afneemt van meer dan 600 mm in het oosten tot minder dan 300 mm in het westen. Bovendien bestaat er een oplopende gradiënt in temperatuur, vooral in de gemiddelde dagelijkse maxima voor de warmste maand, in bewolking, in verdamping en in het gemiddelde verzadigingstekort. Dit heeft tot gevolg dat er een gradiënt van klimaten heerst van relatief vochtig, gematigd tropisch in het oosten, via een droger steppenklimaat tot een droog woestijnachtig klimaat in het westen. Als gevolg van topografische verschillen, die evenwel in het oosten veelvuldiger voorkomen dan in het westen, zijn er binnen het studiegebied tamelijk grote verschillen in meso- en microklimaten.

Van oost naar west stroomt de rivier over telkens oudere, Mesozoïsche en laat-Palaeozoïsche afzettingen van het Karoo Systeem, en wel achtereenvolgens over afzettingen behorende tot de Stormberg Serie, de Beaufort Serie, de Ecca Serie en de Dwyka Serie. De Dwyka afzettingen worden hier en daar door Precambrische lava van het Ventersdorp Systeem onderbroken, terwijl doleriet-intrusies regelmatig in alle afzettingen voorkomen. Tertiaire en recente aeolische zanden en kalkbanken worden in het westelijke deel van het studiegebied aangetroffen en alluviale afzettingen komen hier en daar verspreid over het studiegebied voor.

In geomorfologisch opzicht is er ook een gradiënt. In het oosten is het landschap vrij sterk versneden, terwijl in het westen de eentonigheid van de vlakten slechts hier en daar door een inselberg of enkele pannen wordt onderbroken.

Binnen het studiegebied variëren de bodemsoorten van de prairiebodems van het Hogeveld in het oosten, via de solonetzen tot de zandige en kalkrijke woestijnbodems in het westen. Ondiepe lithosolen komen algemeen in het gebied voor.

Het studiegebied omvat een verscheidenheid aan vegetatietypen, wisselend van graslanden in het oosten, via open dwergstruiken- en grassengemeenschappen tot een open dwergstruiksteppe in het westen. Op de hellingen groeit gewoonlijk een open, struikvegetatie en op het Kalahari-zand in het meest westelijke deel van het studiegebied wordt af en toe een open boomsavanne aangetroffen. De rivier is vrijwel overal door een oeverbos omzoomd.

Gemengd boerenbedrijf is de algemene bestaansvorm in het oostelijke deel van het studiegebied, terwijl in het westen vooral uitgestrekte veeteeltboerderijen worden aangetroffen.

In hoofdstuk III wordt in het kort de fytogeografische literatuur die op het studiegebied betrekking heeft, besproken. Een belangrijke chorologische grens, namelijk die tussen de Sudano-Zambesische en de Karoo-Namib Regio, doorsnijdt het studiegebied juist stroomafwaarts van Petrusville. Deze grens valt samen met de grens tussen het versneden en het vlakke landschap. In het oostelijke deel van het studiegebied is het Afro-montane element goed vertegenwoordigd. Het Kaapse element ontbreekt vrijwel geheel in de flora van het studiegebied. Er zijn lijsten opgenomen van soorten, die in het studiegebied voorkomen en die een Afro-montaan, een Afro-montaan-Kaaps, een Kaaps, een Sudano-Zambesisch, een Karoo-Namib en een "Centraal" verspreidingspatroon vertonen. Ook is er een lijst van soorten met verspreidingspatronen die niet als voorbeelden voor deze plantengeografische indeling kunnen gelden.

In hoofdstuk IV worden de diverse opvattingen met betrekking tot de vegetatiekunde geschetst en de plaats die de opvattingen van de School van Zürich-Montpellier hieromtrent innemen, besproken. Er wordt op gewezen, dat vroeger rivaliteit tussen de diverse benaderingswijzen een opvallende trek in de vegetatiekunde was, maar dat de ontwikkeling van nieuwe technieken en heldere definities van begrippen geleidelijkaan tot een wederzijds begrip bij de verschillend georiënteerde vegetatiekundigen heeft geleid. De betekenis van de benaderingswijze van de School van Zürich-Montpellier met betrekking tot de vegetatiekunde wordt beklemtoond door er op te wijzen, dat ze wetenschappelijk verantwoord en doelmatig is en een plooibare classificatie op een praktisch bruikbaar niveau van gedetailleerdheid oplevert.

In hoofdstuk V worden de begrippen en technieken van de School van Zürich-Montpellier toegelicht. De analytische fase, die het maken van opnamen omvat, alsmede de synthetische fase in het vegetatieonderzoek worden uitvoerig besproken, en de manier, waarop de begrippen en methoden van de School van Zürich-Montpellier in het huidige onderzoek gebruikt zijn, wordt uiteengezet. Aan het einde van hoofdstuk V wordt een theoretische definitie van het studiegebied gegeven en er wordt aangeduid hoe deze definitie in de praktijk geïnterpreteerd is.

Hoofdstuk VI behandelt de plantengemeenschappen, hun structuur, standplaats, verspreiding binnen het studiegebied en syntaxonomische rang. Alle syntaxa worden voor de eerste keer beschreven.

Het oeverbos langs de Boven-Oranje bestaat uit twee associaties, het Rhoo-Diospyretum en het Zizipho-Acacietum karroo, die beide tot het verbond Diospyrion lycioidis behoren. Het Rhoo-Diospyretum is onderverdeeld in de subassociaties celtidetosum en acacietosum karroo, terwijl er binnen het celtidetosum nog een variant met *Acacia karroo* is onderscheiden. Deze syntaxa komen in een geografische reeks in het studiegebied voor, hetgeen waarschijnlijk door de klimaatsgradiënt bepaald wordt. Er worden nog enkele rivieroevergemeenschappen besproken, die slechts over een klein gebied voorkomen en derhalve betrekkelijk onbelangrijk zijn.

Binnen de graslandvegetatie in het oostelijke deel van het studiegebied worden drie gemeenschappen onderscheiden, waaraan echter geen syntaxonomische rang is verleend.

Eén associatie, het Hermannio coccocarpae-Nestleretum confertae, met drie subassociaties, het aptosimetosum marlothii, het eragrostietosum curvulae en het oropetietosum, en een variant met *Eragrostis lehmanniana*, wordt er beschreven van de gras- en dwergstruikvegetatie van de vlakten in het centrale deel van het studiegebied. De verschillen in standplaats tussen deze drie subassociaties en de variant worden kort besproken. De associatie behoort tot het verbond Pentzio-Chrysocomion, dat voorlopig wordt beschreven.

De open struikgemeenschappen van de hellingen in het oostelijke en centrale deel van het studiegebied behoren alle tot de klasse Rhoetea erosae, waarbinnen twee orden zijn onderscheiden. De Grewio-Rhoetalia erosae komen op matig vochtige plaatsen, voornamelijk ten oosten van Aliwal-Noord voor en omvatten drie associaties: het Rhamno-Rhoetum op naar het zuiden gerichte hellingen, het Rhoo-Aloetum ferocis op naar het noorden gerichte hellingen en het Blepharido-Rhoetum op niet te droge plaatsen in de omgeving van Aliwal-Noord. De eerstgenoemde twee associaties behoren tot het verbond Indigofero spinescentis-Rhoion erosae. Het Afro-montane en het Afro-montaan-Kaapse element zijn goed in de Grewio-Rhoetalia erosae vertegenwoordigd, vooral in het Rhamno-Rhoetum. De Rhoetalia ciliato-erosae omvatten bijna alle open struikgemeenschappen in de streek tussen Aliwal-Noord en Petrusville. Vijf associaties behoren ertoe: het Osteospermetum leptolobi met de subassociaties typicum en aptosimetosum marlothii, op nauwelijks hellend terrein met ondiepe bodems op zandsteen; het Stachyo-Rhoetum, dat vooral op noordwaarts gerichte doleriethellingen voorkomt en waartoe de subassociaties polygaletosum en hermannietosum candidissimae en, in de omgeving van Petrusville, een variant met *Salvia namaensis* behoren; het Nanantho vittati-Rhoetum, dat voornamelijk tot naar het noorden gerichte zandsteenhellingen in de omgeving van Bethulie beperkt is; het Mayteno polyacanthae-Oleetum africanae met de subassociaties typicum en chamareetosum, dat hoofdzakelijk op naar het zuiden gerichte doleriethellingen voorkomt; en het Setario lindenbergianae-Buddleietum salignae, dat in de omgeving van Petrusville gewoonlijk juist onder de toppen van dolerietbergen voorkomt. Het Osteospermetum leptolobi, het Stachyo-Rhoetum en het Nanantho vittati-Rhoetum behoren tot het verbond Hibisco marlothiani-Rhoion erosae. De westelijke grens van het verspreidingsgebied van de Rhoetea erosae valt binnen het studiegebied samen met de grens tussen de Sudano-Zambesische en de Karoo-Namib Regio.

De open struik- en dwergstruikgemeenschappen op rotsachtige bodem in het gebied ten westen van Petrusville behoren voor het merendeel tot de klasse Pentzietea incanae, waarvan vijf associaties beschreven worden: het Zizipho-Rhigozetum obovati met de subassociaties cheilanthetosum eckloniana en inops, voornamelijk voorkomend op doleriethellingen in de streek tussen Skurwekop en Hopetown; het Melhanio rehmannii-Hermannietum spinosae, dat op hellingen van andesitische lava stroomafwaarts van Hopetown voorkomt; het Monechmatetum incani met de subassociaties typicum en pentzietosum calcareae, dat op alkalische bodems voorkomt op plaatsen met een concentratie van afvloeiend oppervlaktewater; het Nestlero humilis-Pteronietum sordidae met de subassociaties typicum en stipagrostietosum ciliatae, dat op kalkrijke substraten stroomafwaarts van Orania voorkomt; en het Eriocephalo-Eberlanzietum, dat op niet of nauwelijks hellende, iets zure, lemige zandgronden voorkomt in de streek tussen Skurwekop en Hopetown. Het Zizipho-Rhigozetum obovati en het Melhanio rehmannii-Hermannietum spinosae behoren tot het verbond Enneapogono scabri-Rhigozion obovati; het Monechmatetum incani en het Nestlero humilis-Pteronietum sordidae tot het verbond Zygophyllion gilfillani. De beide verbonden zijn in de orde Pentzio incanae-Rhigozetalia trichotomi verenigd.

Op Kalahari-zand komen er binnen het studiegebied twee associaties voor: het Enneapogono brachystachyi-Stipagrostietum op iets lemig zand en het Pentzio calcareae-Stipagrostietum op zuiver Kalahari-zand waaronder zich kalkbanken hebben ontwikkeld. De laatstgenoemde associatie omvat de subassociaties typicum en acacietosum giraffae. Beide associaties behoren, tezamen met enkele reeds vroeger van de zuidelijke Kalahari beschreven associaties, tot het verbond Stipagrostion, dat hier voorlopig wordt onderscheiden.

Aan het einde van hoofdstuk VI worden enkele gemeenschappen beschreven die slechts een kleine oppervlakte beslaan binnen het studiegebied. Deze worden syntaxonomisch niet ingedeeld.

In hoofdstuk VII wordt een overzicht gegeven van de oecologische en syntaxonomische gradiënt binnen het studiegebied, waarbij de nadruk valt op klimaatsverschillen en verschillen in samenstelling en structuur van de gemeenschappen. Er worden, op basis van de vochthuishouding van de diverse bodemsoorten, drie parallele series van gemeenschappen van gematigd vochtig tot droog opgesteld en de mate, waarin de habitatstoestanden in soortensamenstelling en gemeenschapsstructuur tot uitdrukking komen, wordt besproken. Tot slot worden er enkele korte opmerkingen gemaakt over het verband tussen de invloed van wanbeheer van de vegetatie en de diversiteit ervan en van het landschap.

Een lijst van in de opnamen voorkomende soorten en een index van genera naar families worden in appendices gegeven.

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APPENDIX 1

INFREQUENT SPECIES OCCURRING IN THE RELEVéS OF TABLE VI.1.1 (DIOSPYRION LYCIOIDIS)

Althernanthera pungens 512:+; 516:+
Argemone subsusiformis 420:1; 489:+
Asparagus denudatus 235:+
Asparagus laricinus 235:+; 223:+
Ballota africana 35:1; 388:1;
Boscia albitrunca 489:+
Buddleia salviifolia 250:+
Chloris virgata 454:+
Convolvulus boedeckerianus 35:+
Cynodon hirsutus 327:2b
Ehretia rigida 133:+
Enneapogon brachystachyus 101:1
Equisetum ramosissimum 162:1
Eragrostis curvula 171:1; 105:r
Hebenstreitia dentata 5:r
Hertia pallens 154:+
Leucas martinicensis 398:1; 489:+
Loranthus oleaefolius 506:+
Maytenus heterophylla 207:+; 149:+
Oenothera stricta 5:+
Olea africana 189:r; 312:r
Panicum laevifolium 448:+
Pavonia burchellii 506:1
Pentzia calcarea 516:r
Phragmites communis 162:+
Phytolacca heptandra 118:+
Pollichia campestris 347:+; 493:+
Psilocaulon absimile 420:+
Rhus lancea 448:2b
Rhus undulata var. *burchellii* 301:1
Salix babylonica 200:+
Salix capensis 415:+
Salsòla kali 427:+
Selago albida 50:1
Solanum incanum 418:+
Solanum supinum 482:+
Talinum caffrum 215:+; 56:+
Tragus berteronianus 454:+
Verbena bonariensis 250:+
Verbesina encelioides var. *encelioides* 493:1
Withania somnifera 207:+; 199:+
Xanthium spinosum 502:+
Xanthium strumarium 454:+

APPENDIX 2

INFREQUENT SPECIES OCCURRING IN THE RELEVéS OF TABLE VI.2 (EASTERN GRASSLANDS)

Aloinopsis spec. 213:r
Argyrolobium pauciflorum 239:+
Asclepias fruticosa 229:r
Blepharis integrifolia 224:+
Eustachys paspaloides 213:+
Galenia secunda 220:+
Geigeria filifolia 214:+
Gerbera viridifolia 274:+
Gnidia polycephala 205:+
Harpochloa falx 251:+
Helichrysum latifolium 274:+
Helichrysum rosum 251:+
Hermannia quartiniana 236:+
Hibiscus pusillus 242:+
Indigofera bifrons 271:+
Koeleria cristata 239:+
Lasiospermum bipinnatum 246:1
Lessertia pauciflora 205:+
Lightfootia denticulata 229:+; 213:+
Linum thunbergii 251:+
Lycium salinicolum 205:+
Melolobium microphyllum 239:+
Monsonia biflora 214:+
Nenax microphylla 224:+
Nolletia ciliaris 239:+
Panicum stapfianum 246:+
Pelargonium sidifolium 220:+
Pennisetum sphacelatum 246:+
Polygala amatymbica 236:+
Rhus erosa 225:+
Rhus undulata var. *burchellii* 225:+
Schizoglossum capense 205:+
Schistostephium crataegifolium 239:+
Senecio inornatus 239:+
Senecio latifolius 239:+
Senecio retrorsus 260:+
Sonchus dregeanus 220:+
Stapelia flavirostris 257:+
Striga bilabiata 251:+
Sutera caerulea 234:+
Sutera kraussiana 213:+
Triraphis andropogonoides 232:+
Vahlia capensis 214:+
Vernonia oligocephala 274:+
Zaluzianskya capensis 251:+

APPENDIX 3

INFREQUENT SPECIES OCCURRING IN THE RELEVÉS OF TABLE VI.3 (HERMANNIO COCCOCARPAE-NESTLERETUM CONFERTAE)

Atriplex semibaccata 163:+; 546:r
Barleria rigida 287:+
Berkheya discolor 212:+
Blackiella inflata 282:+
Blepharis villosa 287:+
Brachiaria serrata 180:+
Chascanum pinnatifidum 201:r; 40:+
Chasmatophyllum musculinum 146:+
Cineraria lobata 22:+
Commelina africana 196:+; 154:+
Crassula filamentosa 155:r; 147:1
Crassula setulosa 555:r
Cymbopogon plurinodis 217:1; 555:r; 191:+
Cyphocarpha angustifolia 277:+; 326:+
Dianthus basuticus subsp. *basuticus* 217:+
Dicoma macrocephala 287:+
Digitaria eriantha 212:+; 180:+; 555:+
Eriocephalus pubescens 326:2a
Euphorbia clavarioides 255:+
Eustachys paspaloides 175:+
Galenia secunda 181:+; 164:r; 147:r
Helichrysum lucilioides 282:+
Heliotropium ciliatum 1:+
Hermannia depressa 217:r; 212:1; 184:+
Hermannia pulchra 280:+
Hermannia pulverata 546:+
Hermannia resedaefolia A:+; 1:r
Heteropogon contortus 155:+; 307:r
Kohautia amatymbica 40:1; 103:1; 59:+
Lightfootia denticulata 40:+; 103:+; 110:+
Lithospermum cinereum 67:r
Lotononis laxa 139:+; 19:1
Lotononis tenella 279:r; 326:+; 24:+
Lycium pilifolium 542:2a
Monsonia angustifolia 175:+
Nananthus vittatus 128:+
Nestlera prostrata 326:+; 546:1
Nolletia ciliaris 196:+
Osteospermum leptolobum 19:+; 69:+
Panicum coloratum 73:1
Pegolettia retrofracta 283:1
Pelargonium fumarioides 537:+
Pentzia lanata 134:1
Phymaspermum parvifolium 282:+; 157:+
Plinthus sericeus 22:3
Polugala leptophylla 318:+; 283:+; 117:+
Polygala uncinata 100:r
Psammotropha mucronata 280:+; 282:+
Rhus ciliata 279:+
Ruschia spec. 202:+
Setaria flabellata 175:+
Sporobolus discosporus 69:+; 84:+
Sporobolus ludwigii 73:+
Stachys burchelliana 147:+
Stipagrostis obtusa 279:2a; 326:2a
Sutera albiflora 70:+; 40:1
Sutera aurantiaca 212:+
Tetragonia arbuscula 12:+
Thesium spartioides 139:+
Tragus berteronianus 546:1; 551:+

APPENDIX 4

INFREQUENT SPECIES OCCURRING IN THE RELEVéS OF TABLE VI.4 (GREWIO-RHOETALIA EROSAE)

Ajuga ophrydis 259:+; 221:+
Aloe grandidentata 266:+
Anacampseros lanigera 216:+; 170:+
Aptosimum depressum 172:+; 170:+
Aristida curvata 233:+
Asclepias fruticosa 264:+
Asparagus asparagoides 237:+
Asparagus microraphis 243:+
Asplenium adiantum-nigrum 230:+; 240:+
Aster serrulatus 243:2b; 230:+
Blechnum australe 268:1
Blepharis transvaalensis 172:r
Bowkeria verticillata 267:4
Buddleia salviifolia 267:+; 243:1; 230:+
Centella coriaceae 241:+
Ceterach cordatum 273:+; 254:+
Chamarea capensis 206:+
Cineraria aspera 206:r
Cineraria lobata 243:+; 238:+; 230:+
Cineraria mollis 243:+
Convolvulus boedeckerianus 256:+
Conyza podocephala 221:+; 174:+
Crabbea hirsuta 247:+; 245:+
Crassula lycopodioides 197:+
Crassula nodolosa 228:+; 238:+
Cymbopogon excavatus 245:2b; 233:1
Cynoglossum hispidum 245:+
Danthonia disticha 226:+
Dicoma anomala 264:+; 222:+; 219:+
Eragrostis chloromelas 536:+; 556:+
Eragrostis gummiflua 221:r; 241:+
Eragrostis superba 230:+
Erica caffra 240:2b
Euphorbia clavarioides 265:+; 170:+
Euphorbia striata 238:+
Euryops floribundus 243:+
Falkia repens 266:+
Festuca caprina 243:+
Festuca longipes 264:+; 238:+
Gnidia capitata 228:+; 222:+
Gnidia microcephala 200:+; 238:+
Hebenstreitia fruticosa 240:+
Helichrysum caespititium 268:+
Helichrysum ericaefolium 270:+; 248:+; 221:+
Helichrysum infaustum 258:+
Helichrysum rugulosum 264:+; 269:+
Helichrysum setosum 259:+; 240:+
Helichrysum subglomeratum 270:+
Helichrysum zeyheri 256:+
Hermannia coccocarpa 179:+
Huernia spec. 254:+
Leonotis mollis 261:+
Leucophrys mesocoma 211:r
Leucosidea sericea 179:+; 243:2b
Linum thunbergii 536:+
Lippia javanica 242:+
Listia heterophylla 221:+; 174:+
Lithospermum affine 259:+
Lotononis laxa 187:+, 170:+
Lotononis tenella 231:+; 221:+

Massonia bowkeri 268:+
Maytenus undata 233:r; 231:1
Medicago aschersoniana 233:+
Melolobium microphyllum 187:+; 200:+
Metalasia muricata 238:+
Microchloa caffra 265:+
Miscanthidium sorghum 230:+
Nananthus spec. 172:+
Nolletia ciliaris 219:+; 269:+
Oenothera indecora 230:+
Oenothera rosea 233:r
Panicum stapfianum 536:+
Pegolettia retrofracta 170:1
Pelargonium aridum 254:+; 197:+
Pelargonium cardiophyllum 179:+
Pelargonium myrrhifolium 221:+
Peucedanum connatum 536:+
Phyllanthus maderaspatensis 185:+; 172:+
Phymaspermum aciculare 209:+
Polygala uncinata 536:+
Printzia polifolia 210:+
Pterothrix spinescens 211:+
Rhigozum obovatum 209:+
Rhus dregeana 243:+; 230:1
Rhynchosia adenodes 221:+; 179:+
Rhynchosia nervosa 231:+
Rosa rubiginosa 248:1
Rubia cordifolia 268:+; 248:+; 536:r
Rubus cuneifolius 268:+; 248:+
Rubus ludwigii 238:+; 233:+
Salsola glabrescens 203:+
Schistostephium crataegifolium 238:+; 247:+; 245:+
Senecio burchellii 206:r
Senecio inornatus 238:+
Solanum incanum 233:+
Sutera aurantiaca 243:r
Sutera caerulea 238:+
Sutera griquensis 268:+
Thesium spartioides 170:+
Trachypogon spicatus 240:+
Trichodiadema pomeridianum 536:+; 174:r; 170:+
Venidium microcephalum 259:+; 237:+; 268:2a
Withania somnifera 267:1; 233:+
Zaluzianskya capensis 238:+

APPENDIX 5

INFREQUENT SPECIES OCCURRING IN THE RELEVéS OF TABLE VI.5 (RHOETALIA CILIATO-EROSAE)

Acacia mellifera subsp. *detinens* 351:+
Achyranthes aspera 552:+; 98:+
Aloinopsis spec. 541:+; 313:+; 32:2a
Anacampseros rufescens 173:+
Antizoma capensis 132:+; 130:+
Aptosimum leucorrhizum 292:+; 299:+; 82:+
Argemone subfusiformis 290:r
Asparagus setaceus 97:+; 38:+
Atriplex semibaccata 108:r; 324:+; 29:r
Berkheya radula 552:+
Boophane disticha 338:+
Boscia albitrunca 292:r; 299:r; 324:+
Caralluma lutea 549:+
Cenchrus ciliaris 173:1; 351:+; 545:2a
Ceterach cordata 115:1
Chasmatophyllum musculinum 148:+
Cheilanthes depauperata 89:+
Chloris virgata 335:r; 544:+
Cineraria lobata 550:+; 127:r; 29:+
Clematis brachiata 176:r; 136:r
Cleome angustifolia 286:+
Commelina africana 153:+; 98:+; 148:+
Conyza podocephala 153:+
Crassula acutifolia 51:+; 77:1
Crassula cooperi 286:+; 290:+
Crassula lycopodioides 541:+
Crassula transvaalensis 90:+
Cyperus usitatus 148:+
Dicoma anomala 176:+
*Dimorphotheca cuneata*111:+; 62:+; 51:1
Enneapogon scaber 292:+; 299:+
Eragrostis denudata 544:+; 538:+
Euphorbia mauritanica 188:+; 332:+; 331:2a
Euphorbia rectirama 336:+; 334:2a
Euphorbia rhombifolia 168:+
Euryops annae 89:2b
Gerbera piloselloides 552:+; 115:+
Gnidia capitata 549:+
Helichrysum aureum 127:r
Helichrysum cerastioides 544:+
Heliotropium ciliatum 49:1
Hermannia depressa 552:+
Hermannia filifolia 152:r; 150:2a
Hermannia resedaefolia 3:r; 130:+
Heteromorpha arborescens 38:+
Hibiscus aethiopicus 111:+; 115:+
Huernia spec. 148:+
Ifloga caespitosa 286:+
Indigofera bifrons 543:+
Indigofera spinescens 173:+
Ipomoea crassipes 550:+; 176:+
Kalanchoe paniculata 151:+
Kalanchoe thyrsiflora 334:+; 87:+; 538:+; 333:+
Koeleria cristata 176:+; 190:+
Kohautia amatymbica 303:+
Lasiosiphon burchellii 92:1; 93:1
Leucophrys mesocoma 176:+
Lightfootia denticulata 176:+
Linum thunbergii 153:+
Listia heterophylla 188:+
Lithospermum cinereum 37:+

Lotononis brachyloba 368:+
Lotononis tenella 77:+; 303:r
ycium hirsutum 97:r
Melianthus comosus 115:r
Melolobium obcordatum 29:+
Microloma massonii 322:+
Monsonia angustifolia 547:+; 538:+
Myrsine africana 188:1
Nemesia capensis 305:+; 324:1
Nemesia hanoverica 336:+
Nestlera humilis 319:+
Pavonia burchellii 138:r; 98:1
Pellaea quadripinata 539:+
Pentzia incana 368:2a; 43:1
Phaeoptilum spinosum 368:+
Polygala asbestina 368:+; 29:+
Polygala hottentotta 338:+
Polygala spec. (Werger 1084) 543:+; 62:1
Rhamnus prinoides 188:+
Rhigozum trichotomum 380:1
Rhus viminalis 343:r
Rhynchosia confusa 541:1
Rubia cordifolia 77:r
Ruschia spec. 549:+; 62:1
Sarcostemma viminale 541:+; 304:+; 129:1
Scabiosa columbaria 29:1
Schizoglossum linifolium 121:+
Selago zeyheri 83:+
Senecio burchellii 343:+
Setaria flabellata 99:+
Setaria verticillata 319:1
Silene capensis 108:+
Solanum incanum 296:+
Stapelia olivacea 290:+
Stipagrostis zeyheri subsp. *sericans* 3:2b; 538:1
Sutera caerulea 57:r
Sutherlandia humilis 541:+
Thesium hystrix 368:+
Titanopsis spec. 62:+
Tragus berteronianus 545:+; 550:+
Trichoneura grandiglumis 535:+; 176:+
Turbina oenotheroides 333:+
Walafrida geniculata 343:+; 290:+
Withania somnifera 336:+; 98:+; 538:+
Zinnia multiflora 539:+

APPENDIX 6

INFREQUENT SPECIES OCCURRING IN THE RELEVÉS OF TABLE VI.6 (PENTZIETEA INCANAE)

Adromischus rupicola 300:+
Aizoon burchellii 519:+
Aizoon schellenbergii 481:+; 488:+
Aloe hereroensis 344:1
Anacampseros lanigera 432:+
Aptosimum lineare 497:+; 428:+
Argyrolobium pauciflorum 346:+
Aster filifolius 352:+; 371:+
Asparagus capensis 532:+
Asperagus racemosus 570:+; 503:+
Chloris virgata 422:+; 346:+
Cleome angustifolia subsp. *diandra* 302:1; 340:+; 300:1
Commicarpus pentandrus 453:+
Convolvulus boedeckerianus 437:+
Cotyledon decussata-orbiculata compl. 360:1; 344:+
Crassula acutifolia 473:+
Crassula lycopodioides 300:+; 530:+; 470:+
Crassula setulosa 457:1
Crassula transvaalensis 340:+
Cyperus usitatus 532:1; 464:+
Cypholepis yemenica 478:+; 510:+; 483:+
Dianthus basuticus subsp. *basuticus* 358:1; 457:1
Diospyros lycioides subsp. *lycioides* 302:1; 453:+; 409:+
Drosanthemum spec. 354:+
Eragrostis bicolor 431:+; 498:+; 464:+
Eragrostis brizantha 515:+
Eragrostis curvula 358:+; 346:+; 520:+
Eragrostis echinochloidea 529:+; 475:+; 519:+
Euclea crispa 302:+; 386:+
Euclea undulata 425:1
Euphorbia arida 430:+
Euphorbia rhombifolia 360:2b; 410:+
Fockea angustifolia 371:+
Galenia pubescens 492:+
Helichrysum ericaefolium 409:+; 399:r
Helichrysum zeyheri 407:+
Hermannia abrotanoides 501:+; 495:+
Hermannia coccocarpa 453:+; 464:+
Hertia pallens 457:+; 437:1; 428:+
Hyparrhenia hirta 407:1; 340:+
Indigofera hololeuca 451:+; 501:+
Indigofera teixeirae 476:+; 483:+
Kalanchoe rotundifolia 300:+
Kalonchoe thyrsiflora 360:+
Lightfootia albens 407:+; 358:1; 422:+
Lightfootia nodosa 339:+
Lophiocarpus polystachyus 473:+
Lotononis clandestina 348:1
Lotononis laxa 340:r
Lotononis tenella 345:r; 425:r
Lycium tenue 361:+
Melhania prostrata 348:+
Melianthus comosus 409:+
Melolobium candicans 500:+
*Mohria caffrorum*386:+
Monsonia ovata subsp. *glauca* 434:r
Nemesia capensis 520:+
Nestlera laxa 463:r; 464:+
Nolletia arenosa 494:+; 411:+ 354:r
Nymannia capensis 520:+; 529:+
Osteospermum leptolobum 451:+

Osteospermum scariosum 466:+; 522:+
Panicum laevifolium 457:1
Pentzia pinnatisecta 354:2a
Pentzia sphaerocephala 340:+
Phymaspermum parvifolium 451:+; 435:+; 464:1
Psammotropha mucronata 302:+; 409:1; 459:+
Pteronia mucronata 430:1
Rhus erosa 407:+
Rhus viminalis 300:r
Ruschia spec. 409:r
Salsola rabieana 447:+; 435:+; 460:+
Sarcocaulon patersonii 483:+; 399:+
Schizoglossum longifolium 403:r
Schmidtia pappophoroides 470:+; 522:+
Seddera capensis 348:1; 473:+; 481:+
Senecio radicans 528:+
Setaria lindenbergiana 361:+
Setaria verticillata 386:+; 346:+; 484:+
Stapelia jucunda 437:+
Stipagrostis anomala 451:+; 492:+
Stipagrostis uniplumis var. *uniplumis* 522:+; 500:+
Sutera atropurpurea 443:+
Sutherlandia humilis 302:+
Talinum arnotii 360:+; 411:+
Tephrosia monophylla 473:r
Tetragonia arbuscula 357:+; 436:r; 399:+
Thesium lineatum 424:+; 524:+; 481:+
Walafrida geniculata 446:2b; 376:2a; 447:r

APPENDIX 7

INFREQUENT SPECIES OCCURRING IN THE RELEVéS OF TABLE VI.7 (STIPAGROSTION)

Acacia mellifera subsp. *detinens* 521:1
Antizoma angustifolia 441:+
Aptosimum leucorrhizum 438:+; 485:+
Aristida diffusa var. *burkei* 421:r
Asparagus racemosus 521:+
Brachiaria marlothii 526:+; 523:+
Chloris virgata 526:+
Commelina africana 440:+; 441:+
Convolvulus boedeckerianus 523:+
Cyperus usitatus 355:+
Eragrostis brizantha 525:+; 514:1
Eriocephalus spinescens 402:r; 381:r
Fingerhuthia africana 402:+; 329:r
Geigeria filifolia 355:r
Harpagophytum procumbens subsp. *procumbens* 518:+
Helichrysum arenicola 514:+
Helichrysum ericaefolium 329:+
Hoodia gordonii 421:+
Lessertia pauciflora 421:r; 329:r
Limeum aethiopicum 355:+
Lycium pilifolium 523:+
Lycium tenue 363:1
Melolobium candicans 523:+
Pelargonium fumarioides 518:r
Polygala hottentotta 481:+
Pterothrix spinescens 440:+
Setaria verticillata 526:+
Solanum supinum 526:+
Sporobolus fimbriatus 421:+
Stipagrostis uniplumis var. *uniplumis* 523:+
Talinum caffrum 363:+
Tragus koelerioides 329:+; 525:+
Triraphis fleckii 485:+

APPENDIX 8

CHECK LIST OF SPECIES OCCURRING IN RELEVéS

In the following list all species occurring in the relevés have been included. The Pteridophyta are classified according to SCHELPE (1970). With exception of the Poaceae, the Angiospermae are arranged according to the DE DALLA TORRE & HARMS system (1900-07). The Poaceae are classified according to HUBBARD's (unpublished) system as used at the herbaria of the Royal Botanic Gardens, Kew, and the Botanical Research Institute, Pretoria.

Species which are not taken into account in the phytosociological tables are marked *.

To indicate the life forms the RAUNKIAER system (1934), in the modified version as given by ELLENBERG (1956), has generally been followed.

PTERIDOPHYTA

EQUISETACEAE

G *Equisetum ramosissimum* Desf.

SCHIZAEACEAE

H *Mohria caffrorum* (L.) Desv.

ADIANTACEAE

H *Cheilanthes depauperata* Bak.
H *Cheilanthes eckloniana* (Kunze) Mett.
H *Cheilanthes hirta* Swartz
H *Pellaea calomelanos* (Swartz) Link
H *Pellaea quadripinnata* (Forsk.) Prantl

ASPLENIACEAE

H *Asplenium adiantum-nigrum* L.
H *Ceterach cordatum* (Thunb.) Desv.

BLECHNACEAE

H *Blechnum australe* L.

ANGIOSPERMAE

MONOCOTYLEDONEAE

POACEAE

H *Elyonurus argenteus* Nees
H *Miscanthidium sorghum* (Nees) Stapf
H *Andropogon appendiculatus* Nees
H *Cymbopogon excavatus* (Hochst.) Stapf
H *Cymbopogon plurinodis* (Stapf) Stapf ex Burtt Davy
H *Cymbopogon validus* Stapf ex Burtt Davy
H *Hyparrhenia hirta* (L.) Stapf
H *Trachypogon spicatus* (L.f.) Kuntze
H *Heteropogon contortus* (L.) Beauv. ex Roem. & Schult.
H *Themeda triandra* Forsk.
H *Urochloa panicoides* Beauv.

H	*Digitaria eriantha* Steud.
H	*Leucophrys mesocoma* (Nees) Rendle
H	*Brachiaria marlothii* (Hack.) Stent
H	*Brachiaria serrata* (Thunb.) Stapf
H	*Panicum coloratum* L.
H	*Panicum laevifolium* Hack.
H	*Panicum maximum* Jacq.
H	*Panicum stapfianum* Fourc.
H	*Setaria flabellata* Stapf
H	*Setaria lindenbergiana* (Nees) Stapf
T	*Setaria verticillata* (L.) Beauv.
H	*Rhynchelytrum repens* (Willd.) C.E.Hubb.
H	*Pennisetum sphacelatum* (Nees) Dur. & Schinz
H	*Cenchrus ciliaris* L.
H	*Ehrharta erecta* Lam.
H	*Helictotrichon longifolium* (Nees) Schweick.
H	*Danthonia disticha* Nees
H	*Asthenatherum glaucum* (Nees) Nevski
H	*Pentaschistis setifolia* (Thunb.) McClean
H	*Phragmites communis* Trin.
H	*Agrostis lachnantha* Nees
H	*Aristida bipartita* (Nees) Trin. & Rupr.
TH	*Aristida congesta* Roem. & Schult.
T	*Aristida curvata* (Nees) Trin. & Rupr.
H	*Aristida diffusa* Trin.
H	*Stipagrostis anomala* De Wint.
H	*Stipagrostis ciliata* (Desf.) De Wint. var. *capensis* (Trin. & Rupr.) De Wint.
H	*Stipagrostis obtusa* (Del.) Nees
ChN	*Stipagrostis namaquensis* (Nees) De Wint.
H	*Stipagrostis uniplumis* (Licht.) De Wint. var. *uniplumis*
H	*Stipagrostis zeyheri* (Nees) De Wint. subsp. *sericans* (Hack. apud Schinz) De Wint.
T	*Tragus berteronianus* Schult.
H	*Tragus koelerioides* Aschers.
H	*Sporobolus albicans* Nees
TH	*Sporobolus discosporus* Nees
H	*Sporobolus fimbriatus* Nees
H	*Sporobolus ludwigii* Hochst.
T	*Sporobolus pyramidalis* Beauv.
H	*Eragrostis bicolor* Nees
T	*Eragrostis brizantha* Nees
H	*Eragrostis capensis* (Thunb.) Trin.
H	*Eragrostis chloromelas* Steud.
T	* *Eragrostis cilianensis* (All.) Lutati
H	*Eragrostis curvula* (Schrad.) Nees
H	*Eragrostis denudata* Hack. ex Schinz
H	*Eragrostis echinochloidea* Stapf
H	*Eragrostis gummiflua* Nees
H	*Eragrostis lehmanniana* Nees
H	*Eragrostis obtusa* Munro ex Fical. & Hiern
H	*Eragrostis plana* Nees
T	*Eragrostis porosa* Nees
H	*Eragrostis racemosa* (Thunb.) Steud.
H	*Eragrostis superba* Peyr.
H	*Eragrostis truncata* Hack.
H	*Microchloa caffra* Nees
H	*Cynodon hirsutus* Stent
H	*Cynodon incompletus* Nees
H	*Harpochloa falx* (L.f.) Kuntze
T	*Chloris virgata* Swartz
H	*Eustachys paspaloides* (Vahl) Lanza & Mattei
H	*Oropetium capense* Stapf
T	*Cypholepis yemenica* (Schweinf.) Chiov.
H	*Triraphis andropogonoides* (Steud.) Phill.
T	*Triraphis fleckii* Hack.
H	*Trichoneura grandiglumis* (Nees) Ekman
TH	*Enneapogon brachystachyus* (Jaub. & Spach) Stapf
T	*Enneapogon cenchroides* (Licht.) C.E.Hubb.

H		*Enneapogon scaber* Lehm.
H		*Enneapogon scoparius* Stapf
H		*Schmidtia pappophoroides* Steud.
H		*Fingerhuthia africana* Lehm.
H		*Koeleria cristata* (L.)Pers.
H		*Melica decumbens* Thunb.
T		*Schismus barbatus* (L.) Thell.
H		*Festuca caprina* Nees
H		*Festuca longipes* Stapf
H		*Festuca scabra* Vahl
H		*Bromus willdenowii* Kunth

CYPERACEAE

G		*Cyperus usitatus* Burch.
H		*Mariscus capensis* Schrad.
H		*Kyllinga alba* Nees
T	*	*Bulbostylis humilis* Kunth
H		*Schoenoxiphium sparteum* Kuk.
H		*Carex spicato-paniculata* C.B.Cl.

COMMELINACEAE

H		*Commelina africana* L.

LILIACEAE

G	*	*Ornithoglossum viride* (L.f.) Ait.
G	*	*Bulbine abyssinica* A.Rich.
G	*	*Trachyandra asperata* (Kunth) Oberm.
G	*	*Trachyandra saltii* (Bak.) Oberm.
G	*	*Trachyandra* spec.
G	*	*Anthericum fasciculatum* Bak.
G	*	*Anthericum* spec.
G	*	*Schizobasis intricata* Bak.
G	*	*Eriospermum* spec.
G	*	*Kniphofia* spec.
Ch		*Aloe broomii* Schonl.
Ch		*Aloe claviflora* Burch.
NM		*Aloe ferox* Mill.
Ch		*Aloe grandidentata* Salm-Dyck.
Ch		*Aloe hereroensis* Engl.
Ch		*Haworthia tesselata* Haw.
G	*	*Albuca* spec.
G	*	*Dipcadi marlothii* Engl.
G	*	*Eucomis* spec.
G	*	*Ledebouria revoluta* (L.f.) Jessop
G	*	*Ledebouria* spec.
G	*	*Massonia bowkeri* Bak.
G		*Sansevieria aethiopica* Thunb.
H		*Asparagus asparagoides* (L.) Wight
Ch		*Asparagus capensis* L. var. *capensis*
H		*Asparagus denudatus*(Kunth) Bak.
N		*Asparagus laricinus* Burch.
N		*Asparagus microraphis* (Kunth) Bak.
N		*Asparagus racemosus* Willd.
NM		*Asparagus setaceus* (Kunth) Jessop
Ch		*Asparagus striatus* (L.f.) Thunb.
Ch		*Asparagus suaveolens* Burch.
H		*Asparagus virgatus* Bak.

AMARYLLIDACEAE

G	*	*Haemanthus hirsutus* Bak.
G	*	*Haemanthus* spec.
G		*Boophane disticha* (L.f.) Herb.
G	*	*Brunsvigia radulosa* Herb.

HYPOXIDACEAE

G * *Empodium plicatum* (L.f.) Bak.
G * *Hypoxis angustifolia* Lam.
G * *Hypoxis filiformis* Bak.

IRIDACEAE

G * *Moraea* spec.
G * *Aristea cognata* N.E.Br.
G * *Gladiolus* spec.

DICOTYLEDONEAE

SALICACEAE

M *Salix babylonica* L.f.
M *Salix capensis* Thunb.

ULMACEAE

M *Celtis africana* Burm. f.

LORANTHACEAE

(Ch) *Loranthus oleaefolius* Cham. & Schlechtd.
(Ch) *Viscum rotundifolium* L.f.

SANTALACEAE

N *Osyris lanceolata* Hochst. & Steud.
Ch *Thesium hystrix* A.W.Hill
Ch *Thesium lineatum* L.f.
Ch *Thesium spartioides* A.W.Hill

POLYGONACEAE

T * *Oxygonum alatum* Burch.
T * *Oxygonum* spec.

CHENOPODIACEAE

T *Chenopodium album* L.
T *Chenopodium murale* L.
T * *Chenopodium schraderanum* Roem. & Schult.
Ch *Atriplex semibaccata* R.Br.
HCh *Blackiella inflata* (F.v.Muell.) Aell.
N *Salsola glabrescens* Burtt Davy
T *Salsola kali* L.
N *Salsola rabieana* C.A.Sm. ex Verdoorn
H *Lophiocarpus polystachyus* Turcz.

AMARANTACEAE

T * *Celosia linearis* (Schinz) Schinz
T * *Amaranthus deflexus* L.
T * *Amaranthus schinzianus* Thell.
Ch *Cyphocarpha angustifolia* Lopr.
T * *Pupalia lappacea* (L.) Juss.
H *Achyranthes aspera* L.
T * *Achyranthes sicula* (L.) All.
H *Althernanthera pungens* H.B.K.

NYCTAGINACEAE

H *Commicarpus pentandrus* (Burch.) Heim.

T * *Boerhaavia pterocarpa* S.Wats.
N *Phaeoptilum spinosum* Radlk.

PHYTOLACCACEAE

Ch *Limeum aethiopicum* Burm.
T * *Limeum arenicolum* Schellenb.
T * *Limeum argute-carinatum* Wawra & Peyr.
T * *Limeum fenestratum* (Fenzl) Heim.
T * *Limeum sulcatum* (Kl.) var. *scabridium* (Kl.) Friedr.
Ch *Psammotropha mucronata* (Thunb.) Druce
H *Phytolacca heptandra* Retz.
T *Giesekia africana* (Lour.) Kuntze
T *Giesekia pharnaceoides* L.

AIZOACEAE

H *Corbichonia decumbens* (Forsk.) Exell
Ch *Plinthus cryptocarpus* Fenzl
Ch *Plinthus karooicus* Verdoorn
Ch *Plinthus sericeus* Pax
Ch *Galenia pubescens* (Eckl. & Zeyh.) Druce
Ch *Galenia secunda* (L.f.) Sond.
Ch *Aizoon burchellii* N.E.Br.
Ch *Aizoon schellenbergii* Adamson
N *Tetragonia arbuscula* Fenzl
Ch *Aloinopsis* spec.
Ch *Mestoklema tuberosum* (L.) N.E.Br.
Ch *Nananthus vittatus* (N.E.Br.) Schwant.
Ch *Nananthus* spec.
Ch *Nycteranthus noctiflorus* (L.) Neck.
N *Psilocaulon absimile* N.E.Br.
Ch *Ruschia* spec.
Ch *Titanopsis schwantesii* (Dinter ex Schwant.) Schwant.
Ch *Titanopsis* spec.
Ch *Chasmatophyllum musculinum* (Haw.) Dinter & Schwant.
Ch *Delosperma concavum* L.Bol.
Ch *Delosperma ornatulum* N.E.Br.
Ch *Drosanthemum floribundum* (Harv.) Schwant.
Ch *Drosanthemum* spec.
ChN *Eberlanzia spinosa* Schwant.
Ch *Trichodiadema pomeridianum* L.Bol.

PORTULACACEAE

G *Talinum arnotii* Hook. f.
G *Talinum caffrum* (Thunb.) Eckl. & Zeyh.
Ch *Anacampseros lanigera* Burch.
Ch *Anacampseros rufescens* (Harv.) Sweet
T * *Portulaca oleracea* L.
T * *Portulaca quadrifida* L.

CARYOPHYLLACEAE

H *Pollichia campestris* Soland. in Ait.
T * *Herniaria erkertii* Herm. var. *dewetii* Herm.
H *Silene capensis* Otth
Ch *Dianthus basuticus* Burtt Davy subsp. *basuticus*

RANUNCULACEAE

M *Clematis brachiata* Thunb.

MENISPERMACEAE

H *Antizoma angustifolia* (Burch.) Miers ex Harv.
H *Antizoma capensis* (L.f.) Diels

PAPAVERACEAE

T *Argemone subfusiformis* G.B.Ownb.

BRASSICACEAE

H *Heliophila suavissima* Burch. ex DC.
T * *Lepidium africanum* (Burm.f.) DC.
T * *Lepidium divaricatum* Ait.
T *Sisymbrium burchellii* DC. var. *burchellii*
T * *Raphanus raphanistrum* L.

CAPPARIDACEAE

T *Cleome angustifolia* Forsk. subsp. *diandra* (Burch.) Kers
T * *Cleome monophylla* L.
NM *Boscia albitrunca* (Burch.) Gilg & Ben.
N *Cadaba aphylla* (Thunb.) Wild

RESEDACEAE

H *Oligomeris dipetala* (Ait.) Turcz.

CRASSULACEAE

Ch *Cotyledon decussata-orbiculata* complex
Ch *Kalanchoe paniculata* Harv.
Ch *Kalanchoe rotundifolia* Haw.
Ch *Kalanchoe thyrsiflora* Harv.
Ch *Crassula acutifolia* Lam.
Ch *Crassula cooperi* Reg.
Ch *Crassula filamentosa* Schonl.
Ch *Crassula harveyi* Schonl.
Ch *Crassula lycopodioides* Lam.
Ch *Crassula nodulosa* Schonl.
Ch *Crassula setulosa* Harv.
Ch *Crassula transvaalensis* (Kuntze) K. Schum.
Ch *Adromischus rupicola* C.A.Sm.

SAXIFRAGACEAE

H *Vahlia capensis* Thunb.

ROSACEAE

N *Rubus cuneifolius* Pursh.
N *Rubus ludwigii* Eckl. & Zeyh.
NM *Leucosidea sericea* Eckl. & Zeyh.
ChN *Cliffortia linearifolia* Eckl. & Zeyh.
N *Rosa rubiginosa* L.

MIMOSACEAE

M *Acacia giraffae* Willd.
M *Acacia karroo* Hayne
N *Acacia mellifera* (Vahl) Benth. subsp. *detinens* (Burch.) Brenan
NM *Acacia tortilis* (Forsk.) Hayne subsp. *heteracantha* (Burch.) Brenan

FABACEAE

H *Lotononis brachyloba* Benth.
H *Lotononis clandestina* (E.Mey.) Benth.
H *Lotononis laxa* Eckl. & Zeyh.
T * *Lotononis leptoloba* Bolus
Ch *Lotononis tenella* Eckl. & Zeyh.
H *Listia heterophylla* E.Mey.
Ch *Melolobium candicans* Eckl. & Zeyh.

Ch		*Melolobium microphyllum* Eckl. & Zeyh.
Ch		*Melolobium obcordatum* Harv.
Ch		*Argyrolobium lanceolatum* Eckl. & Zeyh.
Ch		*Argyrolobium pauciflorum* Eckl. & Zeyh.
HCh		*Argyrolobium variopile* N.E.Br.
T	*	*Medicago aschersoniana* Urb.
H		*Indigofera alternans* DC.
Ch		*Indigofera bifrons* E.Mey.
H		*Indigofera hololeuca* Benth.
Ch		*Indigofera sessilifolia* DC.
N		*Indigofera spinescens* E.Mey.
H		*Indigofera teixeirae* Torre
T	*	*Indigofera wilmani* Bak.f. ex Gillett
Ch		*Tephrosia monophylla* Schinz
Ch		*Sutherlandia humilis* Phill. & Dyer
H		*Lessertia pauciflora* Harv.
H		*Rhynchosia adenodes* Eckl. & Zeyh.
H		*Rhynchosia confusa* Benth. & Harv.
HCh		*Rhynchosia totta* (Thunb.) DC.

GERANIACEAE

H		*Monsonia angustifolia* E.Mey.
H		*Monsonia biflora* DC.
H		*Monsonia ovata* Cav. subsp. *glauca* (Knuth) Bawden & T.Muell.
Ch		*Sarcocaulon patersonii* Eckl. & Zeyh. var. *curvatum* Rehm
H		*Pelargonium cardiophyllum* Harv.
H		*Pelargonium fumarioides* L'Herit.
Ch		*Pelargonium myrrhifolium* (L.) Ait.
H		*Pelargonium sidifolium* (Thunb.) R.Kunth
H		*Pelargonium aridum* R.A.Dyer

OXALIDACEAE

G	*	*Oxalis bifurca* Lodd.
G	*	*Oxalis corniculata* L.
G	*	*Oxalis lawsonii* Bol.f.
G	*	*Oxalis obliquifolia* Steud.
G	*	*Oxalis pes-caprae* L.
G	*	*Oxalis* spec.

LINACEAE

H		*Linum thunbergii* Eckl. & Zeyh.

ZYGOPHYLLACEAE

H		*Fagonia minutistipula* Engl.
Ch		*Zygophyllum gilfillani* N.E.Br.
N		*Zygophyllum incrustatum* E.Mey.
T	*	*Tribulus terrestris* L.
T	*	*Tribulus zeyheri* Sond.
N		*Nymannia capensis* (Thunb.) Lindb.

POLYGALACEAE

H		*Polygala amatymbica* Eckl. & Zeyh.
Ch		*Polygala asbestina* Burch.
Ch		*Polygala ephedroides* Burch.
Ch		*Polygala hottentotta* Presl
Ch		*Polygala leptophylla* Burch.
Ch		*Polygala pungens* Burch.
Ch		*Polygala uncinata* E.Mey.
Ch		*Polygala* spec. (Werger 1084)

EUPHORBIACEAE

T * *Phyllanthus burchellii* Muell. Arg.
T * *Phyllanthus incurvis* Thunb.
Ch *Phyllanthus maderaspatensis* L.
T * *Phyllanthus parvulus* Sond.
N *Clutia pulchella* L.
G *Euphorbia aequoris* N.E.Br.
Ch *Euphorbia aggregata* Berg.
Ch *Euphorbia arida* N.E.Br.
Ch *Euphorbia clavarioides* Boiss.
T * *Euphorbia inaequilatera* Sond.
N *Euphorbia mauritanica* L.
N *Euphorbia rectirama* N.E.Br.
N *Euphorbia rhombifolia* Boiss.
H *Euphorbia striata* Thunb.

ANACARDIACEAE

N *Rhus ciliata* Licht.
N *Rhus dentata* Thunb.
N *Rhus divaricata* Eckl. & Zeyh.
N *Rhus dregeana* Sond.
N *Rhus erosa* Thunb.
M *Rhus lancea* L.f.
M *Rhus pyroides* Burch.
N *Rhus undulata* Jacq. var. *burchellii* Schonl.
M *Rhus viminalis* Vahl

CELASTRACEAE

M *Maytenus heterophylla* (Eckl. & Zeyh.) N.Robson
N *Maytenus polyacantha* (Sond.) Marais
M *Maytenus undata* (Thunb.) Blakelock

MELIANTHACEAE

N *Melianthus comosus* Vahl

RHAMNACEAE

M *Ziziphus mucronata* Willd.
NM *Rhamnus prinoides* L'Herit.

TILIACEAE

T * *Corchorus schimperi* Cufod.
N *Grewia flava* DC.
M *Grewia occidentalis* L.

MALVACEAE

Ch *Abutilon austro-africanum* Hochr.
H *Pavonia burchellii* (A.DC.) R.A.Dyer
Ch *Hibiscus aethiopicus* L. var. *ovatus* Harv.
Ch *Hibiscus marlothianus* K. Schum.
Ch *Hibiscus pusillus* Thunb.
T *Hibiscus trionum* L.

STERCULIACEAE

Ch *Melhania griquensis* Bol.
Ch *Melhania prostrata* DC.
Ch *Melhania rehmannii* Szyszyl.
Ch *Hermannia abrotanoides* Schrad.
H *Hermannia argentea* Sm.
Ch *Hermannia candidissima* Spreng.

H	*Hermannia coccocarpa* Kuntze
H	*Hermannia comosa* DC.
N	*Hermannia cuneifolia* Jacq. var. *glabrescens* (Harv.) Verdoorn
H	*Hermannia depressa* N.E.Br.
Ch	*Hermannia desertorum* Eckl. & Zeyh.
ChN	*Hermannia filifolia* L.f.
Ch	*Hermannia linearifolia* Harv.
T	* *Hermannia modesta* (Ehrenb.) Mast.
Ch	*Hermannia pulchra* L.
HCh	*Hermannia pulverata* Andr.
Ch	*Hermannia quartiniana* A.Rich.
H	*Hermannia resedaefolia* (Burch.) R.A.Dyer
Ch	*Hermannia spinosa* E.Mey. ex Harv.
	OCHNACEAE
N	*Ochna atropurpurea* DC.
	HYPERICACEAE
H	*Hypericum aethiopicum* Thunb.
	FLACOURTIACEAE
M	*Kiggelaria africana* L.
	THYMELAEACEAE
Ch	*Gnidia capitata* L.f.
Ch	*Gnidia microcephala* Meisn.
Ch	*Gnidia polycephala* (C.A.Mey.) Gilg
ChN	*Lasiosiphon burchellii* Meisn. var. *glabrifolius* Meisn.
	ONAGRACEAE
H	*Oenothera indecora* Camb.
H	*Oenothera rosea* Ait.
H	*Oenothera stricta* Ledeb.
	ARALIACEAE
M	*Cussonia paniculata* Eckl. & Zeyh.
	APIACEAE
H	*Centella coriacea* Nannfd.
NM	*Heteromorpha arborescens* (Spreng.) Cham. & Schlechtd.
H	*Chamarea capensis* (Thunb.) Eckl. & Zeyh.
H	*Peucedanum connatum* E.Mey.
	ERICACEAE
N	*Erica caffra* L.
	MYRSINACEAE
N	*Myrsine africana* L.
	EBENACEAE
N	*Euclea coriacea* A.DC.
N	*Euclea crispa* (Thunb.)Guerke
NM	*Euclea undulata* Thunb. var. *myrtina* (Burch.) Hiern
N	*Diospyros austro-africana* De Wint.
NM	*Diospyros lycioides* Desf. subsp. *lycioides*

OLEACEAE

M		*Olea africana* Mill.

LOGANIACEAE

NM		*Buddleia saligna* Willd.
NM		*Buddleia salviifolia* (L.) Lam.

APOCYNACEAE

Ch		*Pachypodium succulentum* (L.f.) A.DC.

ASCLEPIADACEAE

Ch		*Microloma massonii* Schltr.
GH		*Schizoglossum capense* (Schltr.) Huber
GH		*Schizoglossum linifolium* Schltr.
G	*	*Schizoglossum* spec.
H		*Asclepias fruticosa* L.
G		*Pentarrhinum insipidum* E.Mey.
Ch		*Sarcostemma viminale* (L.) R.Br.
G		*Orthanthera jasminiflora* (Decne.) Schinz
G		*Brachystelma* spec. (Werger 1623)
Ch		*Hoodia gordonii* (Mass.) Sweet ex Decne.
Ch		*Caralluma lutea* N.E.Br.
Ch		*Stapelia jucunda* N.E.Br.
Ch		*Stapelia flavirostris* N.E.Br.
Ch		*Stapelia olivacea* N.E.Br.
Ch		*Huernia barbata* (Mass.) N.E.Br.
Ch		*Huernia* spec.
GH		*Fockea angustifolia* K.Schum.

CONVOLVULACEAE

(T)	*	*Cuscuta* spec.
Ch		*Falkia repens* L.
Ch		*Seddera capensis* (E.Mey. ex Choisy) Hall.f.
H		*Convolvulus boedeckerianus* Peter
H	*	*Convolvulus ulosepalus* Hall.f.
H		*Ipomoea crassipes* Hook.
H		*Turbina oenotheroides* (L.f.) A.Meeuse

BORAGINACEAE

NM		*Ehretia rigida* (Thunb.) Druce
H		*Heliotropium ciliatum* Kaplan
T	*	*Heliotropium curassavicum* L.
H		*Cynoglossum hispidum* Thunb.
H		*Lithospermum affine* DC.
H		*Lithospermum cinereum* DC.

VERBENACEAE

T		*Verbena bonariensis* L.
Ch		*Lantana rugosa* Thunb.
N		*Lippia javanica* (Burm.f.) Spreng.
H		*Chascanum pinnatifidum* (L.f.) E.Mey.

LAMIACEAE

H		*Ajuga ophrydis* Burch. ex Benth.
H		*Leonotis mollis* Benth.
H		*Leonotis leonitis* R.Br. var. *hirtiflora* (Benth.) Skan
T		*Leucas martinicensis* R.Br.
Ch		*Lasiocorys capensis* Benth.
T		*Ballota africana* (L.) Benth.

H		*Stachys aethiopica* L.
Ch		*Stachys burchelliana* Launert
H		*Stachys rehmannii* Skan
T	*	*Salvia clandestina* L.
Ch		*Salvia namaensis* Schinz
H		*Salvia repens* Burch. ex Benth.
T	*	*Salvia* spec.
Ch		*Satureia biflora* (Buch. Ham ex D.Don) Briq.

SOLANACEAE

N		*Lycium arenicolum* Miers
N		*Lycium austrinum* Miers
N		*Lycium hirsutum* Dunal
ChN		*Lycium pilifolium* C.H.Wright
N		*Lycium prunus-spinosa* Dunal
N		*Lysium salinicolum* Verdoorn
ChN		*Lycium tenue* Willd.
H		*Withania somnifera* Dun.
Ch		*Solanum coccineum* Jacq.
H		*Solanum incanum* L.
T		*Solanum retroflexum* Dun.
Ch		*Solanum supinum* Dun.
NM		*Nicotiana glauca* R.Grah.

SCROPHULARIACEAE

Ch		*Aptosimum albomarginatum* Marl. & Engl.
H		*Aptosimum depressum* Burch.
Ch		*Aptosimum leucorrhizum* (E.Mey.) Phill.
Ch		*Aptosimum lineare* Marl. & Engl.
Ch		*Aptosimum marlothii* Hiern
Ch		*Aptosimum spinescens* (Thunb.) Web.
T	*	*Diascia integerrina* E.Mey. ex Benth.
T		*Nemesia capensis* (Thunb.) Kuntze
T		*Nemesia hanoverica* Hiern
N		*Halleria lucida* L.
N		*Bowkeria verticillata* (Eckl. & Zeyh.) Schinz
Ch		*Sutera albiflora* Verdoorn
Ch		*Sutera atropurpurea* (Benth.) Hiern
Ch		*Sutera aurantiaca* (Burch.) Hiern
HCh		*Sutera caerulea* (L.f.) Hiern
Ch		*Sutera griquensis* Hiern
Ch		*Sutera halimifolia* (Benth.) Kuntze
Ch		*Sutera kraussiana* (Bernh.) Hiern var. *latifolia* Hiern
Ch		*Zaluzianskya capensis* Walp.
Ch		*Hebenstreitia dentata* L.
Ch		*Hebenstreitia fruticosa* Sims
Ch		*Hebenstreitia integrifolia* L.
Ch		*Selago albida* Choisy
Ch		*Selago speciosa* Rolfe
Ch		*Selago zeyheri* Rolfe
Ch		*Walafrida densiflora* Rolfe
Ch		*Walafrida geniculata* Rolfe
Ch		*Walafrida saxatilis* Rolfe
H		*Striga bilabiata* (Thunb.) Kuntze

BIGNONIACEAE

NM		*Rhigozum obovatum* Burch.
N		*Rhigozum trichotomum* Burch.

PEDALIACEAE

G	*	*Harpagophytum procumbens* (Burch.) DC. ex Meissn. subsp. *procumbens*
T	*	*Sesamum capense* Burm.f.

ACANTHACEAE

H		*Crabbea hirsuta* Harv.
H		*Barleria lichtensteiniana* Nees
Ch		*Barleria rigida* Nees
Ch		*Blepharis capensis* (L.f.) Pers.
Ch		*Blepharis integrifolia* (L.f.) E.Mey.
Ch		*Blepharis mitrata* C.B.Cl.
Ch		*Blepharis transvaalensis* Schinz
Ch		*Blepharis villosa* (Nees) C.B.Cl.
Ch		*Monechma desertorum* C.B.Cl.
Ch		*Monechma distichotrichum* (Lindau) P.G.Mey.
H		*Monechma divaricatum* (Nees) C.B.Cl.
Ch		*Monechma incanum* (Nees) C.B.Cl.

RUBIACEAE

H		*Kohautia amatymbica* Eckl. & Zeyh.
HCh		*Anthospermum rigidum* Eckl. & Zeyh.
Ch		*Nenax microphylla* (Sond.) Salter
T		*Rubia cordifolia* L.

DIPSACACEAE

H		*Scabiosa columbaria* L.

CUCURBITACEAE

T	*	*Cucumis* spec.
G	*	*Coccinia sessifolia* (Sond.) Cogn.

CAMPANULACEAE

Ch		*Lightfootia albens* Spreng. ex A.DC.
H		*Lightfootia denticulata* (Burch.) Sond.
Ch		*Lightfootia nodosa* Buek
G	*	*Cyphia triphylla* Phill.

ASTERACEAE

H		*Vernonia capensis* (Houtt.) Druce
H		*Vernonia oligocephala* (DC.) Sch.Bip. ex Walp.
Ch		*Pteronia acuminata* DC.
Ch		*Pteronia acuta* Muschl.
Ch		*Pteronia glauca* Thunb.
Ch		*Pteronia mucronata* DC.
Ch		*Pteronia punctata* Phill.
Ch		*Pteronia sordida* N.E.Br.
Ch		*Aster burkei* Harv.
ChN		*Aster filifolius* Vent.
Ch		*Aster muricatus* Less.
Ch		*Aster serrulatus* Harv.
T	*	*Erigeron floribundus* (H.B.K.) Sch.Bip.
H		*Conyza podocephala* DC.
T	*	*Conyza* spec.
TH		*Nolletia arenosa* O.Hoffm.
Ch		*Nolletia ciliaris* (DC.) Steetz
Ch		*Nolletia gariepina* (DC.) Mattf.
Ch		*Chrysocoma tenuifolia* Berg.
N		*Tarchonanthus camphoratus* L.
T		*Ifloga caespitosa* C.A.Sm.
H	*	*Gnaphalium declinatum* L.f.
T		*Gnaphalium glomerulatum* Sond.
T	*	*Gnaphalium undulatum* L.
T		*Helichrysum arenicola* M.D.Henderson
H		*Helichrysum aureum* (Houtt.) Merrill
Ch		*Helichrysum caespititium* Sond.

TH	*Helichrysum cerastioides* DC.
Ch	*Helichrysum dregeanum* Sond. & Harv.
Ch	*Helichrysum ericaefolium* Less.
Ch	*Helichrysum infaustum* Wood & Evans
H	*Helichrysum latifolium* (Thunb.) Less.
Ch	*Helichrysum lucilioides* Less.
Ch	*Helichrysum niveum* (L.) Less.
H	*Helichrysum nudifolium* (L.) Less.
Ch	*Helichrysum odoratissimum* (L.) Less.
Ch	*Helichrysum rosum* (Berg.) Less.
Ch	*Helichrysum rugulosum* Less.
H	*Helichrysum setosum* Harv.
H	*Helichrysum subglomeratum* Less.
Ch	*Helichrysum zeyheri* Less.
ChN	*Stoebe vulgaris* Levyns
Ch	*Pterothrix spinescens* DC.
ChN	*Metalasia muricata* (L.) Less.
Ch	*Nestlera conferta* DC.
Ch	*Nestlera humilis* Less.
Ch	*Nestlera humilis* Less. *forma*
Ch	*Nestlera laxa* Phill.
Ch	*Nestlera prostrata* Harv.
H	*Athrixia angustissima* DC.
N	*Printzia polifolia* (L.) Hutch.
Ch	*Pegolettia retrofracta* (Thunb.) Kies
Ch	*Geigeria filifolia* Mattf.
T	*Xanthium spinosum* L.
T	*Xanthium strumarium* L.
T	*Zinnia multiflora* L.
T	*Verbesina encelioides* (Cav.) A.Gray var. *encelioides*
T	* *Tagetes minuta* L.
Ch	*Eripcephalus pubescens* DC.
Ch	*Eriocephalus spinescens* Burch.
T	*Lasiospermum bipinnatum* (Thunb.) Druce
T	* *Arctotis* spec.
N	*Phymaspermum aciculare* Benth. & Hook.f.
Ch	*Phymaspermum parvifolium* (DC.) Benth. & Hook.f.
T	* *Bidens bipinnata* L.
H	*Schistostephium crataegifolim* (DC.) Fenzl
H	*Artemisia afra* Jacq.
Ch	*Pentzia calcarea* Kies
Ch	*Pentzia globosa* Less.
Ch	*Pentzia incana* (Thunb.) Kuntze
Ch	*Pentzia lanata* Hutch.
Ch	*Pentzia pinnatisecta* Hutch.
Ch	*Pentzia punctata* Harv.
Ch	*Pentzia sphaerocephala* DC.
N	*Hertia pallens* (DC.) Kuntze
T	* *Cineraria aspera* Thunb.
H	*Cineraria lobata* L'Herit.
H	*Cineraria mollis* E.Mey.
H	*Senecio burchellii* DC.
H	*Senecio erubescens* Ait.
T	* *Senecio glutinosus* Thunb.
H	*Senecio hieracioides* DC.
H	*Senecio inornatus* DC.
H	*Senecio latifolius* DC.
Ch	*Senecio longiflorus* (DC.) Sch.Bip.
Ch	*Senecio radicans* Sch.Bip.
H	*Senecio retrorsus* DC.
ChN	*Euryops annae* Phill.
ChN	*Euryops empetrifolius* DC.
ChN	*Euryops floribundus* N.E.Br.
Ch	*Dimorphotheca cuneata* Less.
G	* *Dimorphotheca zeyheri* Sond.
Ch	*Osteospermum leptolobum* (Harv.) T.Norl.

H		*Osteospermum scariosum* DC.
N		*Osteospermum spinescens* Thunb.
T	*	*Ursinia nana* DC. subsp. *nana*
H		*Venidium microcephalum* DC.
H		*Haplocarpha scaposa* Harv.
H		*Gazania krebsiana* Less.
H		*Hirpicium echinus* Less.
H		*Berkheya discolor* (DC.) O.Hoffm. & Muschl.
H		*Berkheya pinnatifida* (Thunb.) Thell.
H		*Berkheya radula* (Harv.) De Wild.
H		*Dicoma anomala* Sond.
H		*Dicoma macrocephala* DC.
H		*Sonchus dregeanus* DC.
T	*	*Sonchus oleraceus* L.
H		*Gerbera viridifolia* (DC.) Sch.Bip.
H		*Gerbera piloselloides* (L.) Cass.
H		*Lactuca capensis* Thunb.
H	*	*Lactuca serriola* L.

APPENDIX 9

GENUS-FAMILY INDEX

Abutilon	Malvaceae
Acacia	Mimosaceae
Achyranthes	Amaranthaceae
Adromischus	Crassulaceae
Agrostis	Poaceae
Aizoon	Aizoaceae
Ajuga	Lamiaceae
Albuca	Liliaceae
Aloe	Liliaceae
Aloinopsis	Aizoaceae
Alternanthera	Amaranthaceae
Amaranthus	Amaranthaceae
Anacamseros	Portulacaceae
Andropogon	Poaceae
Anthericum	Liliaceae
Anthospermum	Rubiaceae
Antizoma	Menispermaceae
Aptosimum	Scrophulariaceae
Arctotis	Asteraceae
Argemone	Papaveraceae
Argyrolobium	Fabaceae
Aristea	Iridaceae
Aristida	Poaceae
Artemisia	Asteraceae
Asclepias	Asclepiadaceae
Asparagus	Liliaceae
Asplenium	Aspleniaceae
Aster	Asteraceae
Asthenatherum	Poaceae
Athrixia	Asteraceae
Atriplex	Chenopodiaceae

Ballota	Lamiaceae
Barleria	Acanthaceae
Berkheya	Asteraceae
Bidens	Asteraceae
Blackiella	Chenopodiaceae
Blechnum	Blechnaceae
Blepharis	Acanthaceae
Boerhaavia	Nyctaginaceae
Boophane	Amaryllidaceae
Boscia	Capparidaceae
Bowkeria	Scrophulariaceae
Brachiaria	Poaceae
Brachystelma	Asclepiadaceae
Bromus	Poaceae
Brunsvigia	Amaryllidaceae
Buddleia	Loganiaceae
Bulbine	Liliaceae
Bulbostylis	Cyperaceae

Cadaba	Capparidaceae
Caralluma	Asclepiadaceae
Carex	Cyperaceae
Celosia	Amaranthaceae
Celtis	Ulmaceae
Cenchrus	Poaceae
Centella	Apiaceae
Ceterach	Aspleniaceae
Chamarea	Apiaceae
Chascanum	Verbenaceae
Chasmatophyllum	Aizoaceae
Cheilanthes	Adiantaceae
Chenopodium	Chenopodiaceae
Chloris	Poaceae
Chrysocoma	Asteraceae
Cineraria	Asteraceae
Clematis	Ranunculaceae
Cleome	Capparidaceae
Cliffortia	Rosaceae
Clutia	Euphorbiaceae
Coccinia	Cucurbitaceae
Commelina	Commelinaceae
Commicarpus	Nyctaginaceae
Convolvulus	Convolvulaceae
Conyza	Asteraceae
Corbichonia	Aizoaceae
Corchorus	Tiliaceae
Cotyledon	Crassulaceae
Crabbea	Acanthaceae
Crassula	Crassulaceae
Cucumis	Cucurbitaceae
Cuscuta	Convolvulaceae
Cussonia	Araliaceae
Cymbopogon	Poaceae
Cynodon	Poaceae
Cynoglossum	Boraginaceae
Cyperus	Cyperaceae
Cyphia	Campanulaceae
Cyphocarpha	Amaranthaceae
Cypholepis	Poaceae

Danthonia	Poaceae
Delosperma	Aizoaceae
Dianthus	Caryophyllaceae
Diascia	Scrophulariaceae
Dicoma	Asteraceae
Digitaria	Poaceae
Dimorphotheca	Asteraceae
Diospyros	Ebenaceae
Dipcadi	Liliaceae
Drosanthemum	Aizoaceae

Eberlanzia	Aizoaceae
Ehretia	Boraginaceae
Ehrharta	Poaceae
Elyonurus	Poaceae
Empodium	Hypoxidaceae
Enneapogon	Poaceae
Equisetum	Equisetaceae
Eragrostis	Poaceae
Erica	Ericaceae
Erigeron	Asteraceae
Eriocephalus	Asteraceae
Eriospermum	Liliaceae
Euclea	Ebenaceae

Eucomis	Liliaceae
Euphorbia	Euphorbiaceae
Euryops	Asteraceae
Eustachys	Poaceae
Fagonia	Zygophyllaceae
Falkia	Convolvulaceae
Festuca	Poaceae
Fingerhuthia	Poaceae
Fockea	Asclepiadaceae
Galenia	Aizoaceae
Gazania	Asteraceae
Geigeria	Asteraceae
Gerbera	Asteraceae
Giesekia	Phytolaccaceae
Gladiolus	Iridaceae
Gnaphalium	Asteraceae
Gnidia	Thymelaeaceae
Grewia	Tiliaceae
Haemanthus	Amaryllidaceae
Halleria	Scrophulariaceae
Haplocarpha	Asteraceae
Harpagophytum	Pedaliaceae
Harpochloa	Poaceae
Haworthia	Liliaceae
Hebenstreitia	Scrophulariaceae
Helichrysum	Asteraceae
Helictotrichon	Poaceae
Heliophila	Brassicaceae
Heliotropium	Boraginaceae
Hermannia	Sterculiaceae
Herniaria	Caryophyllaceae
Hertia	Asteraceae
Heteromorpha	Apiaceae
Heteropogon	Poaceae
Hibiscus	Malvaceae
Hirpicium	Asteraceae
Hoodia	Asclepiadaceae
Huernia	Asclepiadaceae
Hyparrhenia	Poaceae
Hypericum	Hypericaceae
Hypoxis	Hypoxidaceae
Ifloga	Asteraceae
Indigofera	Fabaceae
Ipomoea	Convolvulaceae
Kalanchoe	Crassulaceae
Kiggelaria	Flacourtiaceae
Kniphofia	Liliaceae
Koeleria	Poaceae
Kohautia	Rubiaceae
Kyllinga	Cyperaceae
Lactuca	Asteraceae
Lantana	Verbenaceae
Lasiocorys	Lamiaceae
Lasiosiphon	Thymeliaceae
Lasiospermum	Asteraceae
Ledebouria	Liliaceae
Leonotis	Lamiaceae
Lepidium	Brassicaceae
Lessertia	Fabaceae
Leucas	Lamiaceae
Leucophrys	Poaceae
Leucosidea	Rosaceae
Lightfootia	Campanulaceae
Limeum	Phytolaccaceae
Linum	Linaceae
Lippia	Verbenaceae
Listia	Fabaceae
Lithospermum	Boraginaceae
Lophiocarpus	Chenopodiaceae
Loranthus	Loranthaceae
Lotononis	Fabaceae
Lycium	Solanaceae
Mariscus	Cyperaceae
Massonia	Liliaceae
Maytenus	Celastraceae
Medicago	Fabaceae
Melhania	Sterculiaceae
Melianthus	Melianthaceae
Melica	Poaceae
Melolobium	Fabaceae
Mestoklema	Aizoaceae
Metalasia	Asteraceae
Microchloa	Poaceae
Microloma	Asclepiadaceae
Miscanthidium	Poaceae
Mohria	Schizaeceae
Monechma	Acanthaceae
Monsonia	Geraniaceae
Moraea	Iridaceae
Myrsine	Myrsinaceae
Nananthus	Aizoaceae
Nemesia	Scrophulariaceae
Nenax	Rubiaceae
Nestlera	Asteraceae
Nicotiana	Solanaceae
Nolletia	Asteraceae
Nycteranthus	Aizoaceae
Nymannia	Zygophyllaceae
Ochna	Ochnaceae
Oenothera	Onagraceae
Olea	Oleaceae
Oligomeris	Resedaceae
Ornithoglossum	Liliaceae
Oropetium	Poaceae
Orthanthera	Asclepiadaceae
Osteospermum	Asteraceae
Osyris	Santalaceae
Oxalis	Oxalidaceae
Oxygonum	Polygonaceae
Pachypodium	Apocynaceae
Panicum	Poaceae
Pavonia	Malvaceae

Pegolettia	Asteraceae
Pelargonium	Geraniaceae
Pellaea	Adiantaceae
Pennisetum	Poaceae
Pentarrhinum	Asclepiadaceae
Pentaschistis	Poaceae
Pentzia	Asteraceae
Peucedanum	Apiaceae
Phaeoptilum	Nyctaginaceae
Phragmites	Poaceae
Phyllanthus	Euphorbiaceae
Phymaspermum	Asteraceae
Phytolacca	Phytolaccaceae
Plinthus	Aizoaceae
Pollichia	Caryophyllaceae
Polygala	Polygalaceae
Portulaca	Portulacaceae
Printzia	Asteraceae
Psammotropha	Phytolaccaceae
Psilocaulon	Aizoaceae
Pteronia	Asteraceae
Pterothrix	Asteraceae
Pupalia	Amaranthaceae

Raphanus	Brassicaceae
Rhamnus	Rhamnaceae
Rhigozum	Bignoniaceae
Rhus	Anacardiaceae
Rhynchelytrum	Poaceae
Rhynchosia	Fabaceae
Rosa	Rosaceae
Rubia	Rubiaceae
Rubus	Rosaceae
Ruschia	Aizoaceae

Salix	Salicaceae
Salsola	Chenopodiaceae
Salvia	Lamiaceae
Sansevieria	Liliaceae
Sarcocaulon	Geraniaceae
Sarcostemma	Asclepiadaceae
Satureia	Lamiaceae
Scabiosa	Dipsacaceae
Schismus	Poaceae
Schistostephium	Asteraceae
Schizobasis	Liliaceae
Schizoglossum	Asclepiadaceae
Schmidtia	Poaceae
Schoenoxiphium	Cyperaceae
Seddera	Convolvulaceae
Selago	Scrophulariaceae
Senecio	Asteraceae
Sesamum	Pedaliaceae
Setaria	Poaceae
Silene	Caryophyllaceae
Sisymbrium	Brassicaceae
Solanum	Solanaceae
Sonchus	Asteraceae
Sporobolus	Poaceae
Stachys	Lamiaceae
Stapelia	Asclepiadaceae
Stipagrostis	Poaceae
Stoebe	Asteraceae
Striga	Scrophulariaceae
Sutera	Scrophulariaceae
Sutherlandia	Fabaceae

Tagetes	Asteraceae
Talinum	Portulacaceae
Tarchonanthus	Asteraceae
Tephrosia	Fabaceae
Tetragonia	Aizoaceae
Themeda	Poaceae
Thesium	Santalaceae
Titanopsis	Aizoaceae
Trachyandra	Liliaceae
Trachypogon	Poaceae
Tragus	Poaceae
Tribulus	Zygophyllaceae
Trichodiadema	Aizoaceae
Trichoneura	Poaceae
Triraphis	Poaceae
Turbina	Convolvulaceae

Urochloa	Poaceae
Ursinia	Asteraceae

Vahlia	Saxifragaceae
Venidium	Asteraceae
Verbena	Verbenaceae
Verbesina	Asteraceae
Vernonia	Asteraceae
Viscum	Loranthaceae

Walafrida	Scrophulariaceae
Withania	Solanaceae

Xanthium	Asteraceae

Zaluzianskya	Scrophulariaceae
Zinnia	Asteraceae
Ziziphus	Rhamnaceae
Zygophyllum	Zygophyllaceae

CURRICULUM VITAE

Marinus Johannes Antonius Werger was born on the 3rd of May 1944 in Enschede, the Netherlands. After following primary and secondary education at Enschede, he enrolled at the State University of Utrecht, the Netherlands, as a student of biology in September 1961. In March 1965 he was awarded his "Candidaats" degree from that University. From September 1965 to April 1966 he studied evolutionary genetics at the State University of Groningen, the Netherlands, under Prof Dr. J.S. Beardmore and Prof. Dr. G.A. van Arkel. In April 1966 he returned to Utrecht to study geomorphology under Prof. Dr. J.I.S. Zonneveld, and to specialize in vegetation science and phytogeography under Prof. Dr. J. Lanjouw, Drs. J.Th. de Smidt and Dr. K.U. Kramer. In November 1968 he was awarded the degree of "Doctorandus". In December 1968 he was engaged on contract as professional research officer at the Botanical Research Institute, Pretoria, South Africa, where he is employed at present.

STELLINGEN

I

Het soortental van de flora van een te bestuderen gebied is irrelevant bij het opstellen van een vegetatie-classificatie van zo'n gebied volgens de methode van Braun-Blanquet.

VAN DONSELAAR, J., 1965. An ecological and phytogeographic study of northern Suriname savannas. Wentia 14:1-163 (p.16).
WERGER, M.J.A., KRUGER, F.J. & TAYLOR, H.C., 1972. A phytosociological study of the Cape Fynbos and other vegetation at Jonkershoek, Stellenbosch. **Bothalia** 10: 599-614 (p.599).

II

Het begrip minimum-areaal berust op een ongeldige hypothese en moet derhalve verworpen worden. De omvang van de proefvlakte wordt bij vegetatie-onderzoek bepaald door de probleemstelling in samenhang met structuur en soortenrijkdom van de betreffende vegetatie.

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

III

De reden, dat de plantensociologische methode van Braun-Blanquet tot voor kort in de Engels sprekende landen onbekend is gebleven, moet eerder gezocht worden in de voorkeur voor een analytische benadering in de Engelstalige wetenschap, in tegenstelling tot de synthetische beschouwingswijze van de Europees-continentale wetenschap, dan in een gebrek aan kennis van de Engelse of Franse taal, of het ontbreken van een bespreking van de tabuleringstechnieken in de diverse handboeken.

IV

De geldigheid van de stelling dat verdelende classificaties van vegetatie beter zijn dan agglomeratieve, moet niet op statistisch-theoretische maar op vegetatie-theoretische overwegingen worden beoordeeld. De stelling is dan onhoudbaar.

LAMBERT, J.M. & Dale, M.B., 1964. The use of statistics in phytosociology. **Adv. Ecol. Res.** 2: 59-99.
PIELOU, E.C., 1969. **An introduction to mathematical ecology.** New York: Wiley.
WILLIAMS, W.T., 1971. Principles of clustering. **Ann. Rev. Ecol. Syst.** 2: 303-326.

V

De ontwikkeling van statistische classificatie- en ordinatiemethoden in de vegetatiekunde heeft een belangrijke bijdrage geleverd tot een betere definitie en rationalisatie van begrippen en technieken, die in de methode van Braun-Blanquet gebruikt worden.

VI

In azonale vegetatie komt facies-vorming meer voor dan in zonale vegetatie.

VII

Een belangrijke factor in de veldverwoesting in Zuid-Afrika is de omstandigheid, dat de in grote aantallen ingevoerde schapen en geiten een aan de plaatselijke oecosystemen vreemd element vertegenwoordigen.

VIII

De oecosystemen van het Richtersveld, Zuid-Afrika, zijn uniek, tot een relatief klein gebied beperkt, en nauwelijks bekend. In verband met het toenemende aantal erts- en mineraalvondsten in deze streek moet hier dringend een gebied van redelijke omvang tot natuurreservaat worden bestemd.

IX

'Long-distance dispersal' voldoet niet ter verklaring van de disjuncte arealen in de flora van de aride gebieden van Amerika.

X

Ofschoon het niet onmogelijk is, dat mais in pre-Columbiaanse tijden door de Arabieren naar Afrika is gebracht, leveren de linguistische verklaringen en mythologische aanduidingen, die van diverse zijden ter staving van deze theorie worden aangevoerd, geen voldoende bewijs hiervan.

XI

In de vroege geschiedenis van de Zuid-Afrikaanse wijnbouw komt Jan van Riebeeck een belangrijker plaats toe dan de beide Van der Stels.

XII

Artikel 11 sub 1 van de promotie-regeling van de Katholieke Universiteit, waarin verboden wordt dat de promovendus de naam van zijn promotor in het dankwoord opneemt, kan geruisloos worden overtreden en dient te vervallen.

XIII

De guerilla-activiteiten langs de Zambezi hebben tot nu toe geen positieve invloed gehad op het bereiken van verandering in het binnenlandse rassenbeleid van de Republiek van Zuid-Afrika. Uitsluiting van Zuid-Afrika van deelname aan internationale sportbijeenkomsten heeft daarentegen wel enige verandering in dit beleid teweeggebracht.

XIV

De stelling van Adam (1969) dat zich in Zuid-Afrika onder wat uiterlijk een rassenconflict lijkt een conflict tussen bezittende en bezitloze klasse afspeelt, gaat voorbij aan de rassenideologische beginselen, die in vele aspecten van de Zuid-Afrikaanse samenleving tot uiting komen.

ADAM, H., 1969. **Südafrika. Soziologie einer Rassengesellschaft.** Frankfurt: Suhrkamp.

Nijmegen, 10 mei 1973 M.J.A. Werger

TABLE VI.2 EASTERN GRASSLANDS

Releve number		275	274	251	271	239	260	257	246	236	249	244	242	234	232	229	225	224	220	214	213	205	Sociability
Eastern longitude	Minutes	33	29	21	20	17	59	54	19	12	22	20	17	12	06	01	58	55	54	48	46	39	
	Degrees	27	27	21	27	27	26	26	27	27	27	27	27	27	27	27	26	26	26	26	26	26	
Southern latitude	Minutes	24	23	18	24	30	36	40	25	28	20	27	27	30	32	31	35	37	39	37	38	39	
	Degrees	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	
Total species number		28	28	27	15	37	20	21	10	20	19	17	19	20	21	23	21	20	22	28	24	18	
Differential species of BRACHIARIA SERRATA-ELYONURUS ARGENTEUS COMMUNITY																							
Bracharia serrata		1	+	2a	+	1		+															2
Elyonurus argenteus			+	3		2b	3	2a		+			+	+			+						2
Hyparrhenia hirta			+	+	+	+		+			+	+											2
Anthospermum rigidum		+	+	+		+	+						+					+	+				2
Eragrostis racemosa		+	2a	2a		+											+						2
Helichrysum niveum		+	+			1		+											+				2
Dianthus basuticus		+		+	+	+																	2
Helichrysum caespititium		1	+	+																			2-3
Ajuga ophrydis				+	+	+																	2
Dicoma anomala		+				+		+							+								2
Cymbopogon excavatus			2b			2b																	2
Helictotrichon longifolium				+		1				+													2
Helichrysum rugulosum		2a	+																				2
Haplocarpha scaposa		+				+																	1-2
Euphorbia striata		+			+																		2
Senecio erubescens				+		+																	2
Differential species of ERAGROSTIS PLANA-ERAGROSTIS GUMMIFLUA COMMUNITY																							
Eragrostis plana		+	+			+			5	2a	2b	2b	1				+			+			2
Eragrostis gummiflua			+				1				+	2a	2b	3			+			1			2
Walafrida densiflora			+						+		+	+		+									1-2
Differential species of PENTZIA GLOBOSA-ERAGROSTIS CURVULA COMMUNITY																							
Pentzia globosa											+		+	+	+	2a	+	2a	1	2a	+	+	1-2
Chrysocoma tenuifolia		+	+								+		+		1	1	+	+		+	+	+	1-2
Eragrostis obtusa											1					+	+	1	1	+		2a	2
Tragus koelerioides								+					r		+	1	+	+			2a	1	2
Aster muricatus								+							+			+		+	+	+	1-2
Hermannia coccocarpa														+		+			+	+			2
Solanum supinum															+	+							2
Kyllinga alba																		+		+			2
Listia heterophylla																			+	+			2
Other species																							
Eragrostis curvula		2a	2a	1	3	3	1	+	2b	1	2b	2a	+	2a	1	1	1	2b	1	3	2a	2a	2
Themeda triandra		+	1	+	1	+	+	+	3	5	+				+	+	1	1	2b	1	+	1	2
Helichrysum dregeanum		+	+	2a		+	1	+			1	2a	2a	1	1	+	+	+	+	+	1	+	2
Aristida congesta		+	+				1	+			2b	1	1	+	2a	+	+	2b	2b	2b	2a	+	2
Heteropogon contortus		2a	+	2a	1	+	+	+		+	1	+		+	+		+	+	1				2
Cymbopogon plurinodis			+	+	1	2a	+	+	2a	+	+			2b			+	1	+	+		+	2
Walafrida saxatilis		+		+		r		+				+	+	+	+	+	+	+	r	+	1	+	1-2
Hermannia depressa		1	1			+	+	+		1	+	+			+	+	+		2a				2
Aristida diffusa				4	1	1	1	2b				+				+	+	1			1		2
Sutera aurantiaca		+	+	+		+				+		+		+		+			+	+		+	2
Cyperus usitatus											2a	2a	1	+	2a	+		+		1	+	+	1-2
Setaria flabellata		+	1		+	1			1	1				1	+	+				+			2
Eragrostis capensis		+	1	+		+	+			+	+	+		+			+						2
Eragrostis lehmanniana					+			+			2b	+	3	r		+				+	+		2
Gazania krebsiana		+	+	+		+	+			+					+	+			+	+			1-2
Euryops annae							r	2b				2a	+		2a	2a	2b	2b					2
Digitaria eriantha					+	+			+					1	+			1	2a	+			2
Convolvulus boedeckerianus		+				+		+												+	+		1-2
Sporobolus fimbriatus										+				1					3	1			2
Aster filifolius		1		r									+		1								2
Trichoneura grandiglumis		+					+						+		+								2
Panicum stapfianum										1												1	2
Lotononis tenella			+				+														+		2
Lactuca capensis		+					+														+		1-2
Berkheya discolor										+				1						+	+		2
Helichrysum ericaefolium							+									+					+	1	2
Cynodon hirsutus											1								+				2-3
Lightfootia albens								+															2
Microchloa caffra		1									+												2
Stoebe vulgaris				+									1										2
Osteospermum scariosum							r													+			1
Oenothera indecora										+			1										2
Hibiscus aethiopicus						+				+													2
Scabiosa columbaria						1															r		2
Pterothrix spinescens																+					+		2

and the species of appendix 2

TABLE VI.7 STIPAGROSTION (prov.)

		Enneapog brach - Stipagrostietum											Pentzia calc - Stipagrostietum																Sociability
													typicum												acacietosum giraffae				
Releve number		329	404	402	374'	381	385	355	362	363	375	421	394	442	445	456	438	440	441	525	521	485	518	514	526	527	523	517	
Eastern longitude	Minutes	10	49	45	41	41	40	39	37	36	25	16	33	23	21	10	00	59	57	53	51	50	47	45	57	56	53	47	
	Degrees	25	24	24	24	24	24	24	24	24	24c	24	24	24	24	24	24	23	23	23	23	23	23	23	23	23	23	23	
Southern latitude	Minutes	27	01	58	57	58'	54c	57	55	55	46	39	50	43	40	37	33	31	30	19	15	18	15	10	19	21	16	14	
	Degrees	30	30	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	
Total species number		13	10	10	11	8	9	20	11	16	7	20	5	17	10	9	14	12	17	13	17	14	10	15	23	20	21	17	
ENNEAPOGONO BRACHYSTACHYI-STIPAGROSTIETUM character and differential species																													
d Enneapogon brachystachyus		+	+	+	1	1	2a	2b	1	2a	2a	2a				+	+			+					1	r		+	2
c Nestlera laxa									1	2b																			1
PENTZIO CALCAREAE-STIPAGROSTIETUM character and differential species																													
d Pentzia calcarea					2a								2a	2a	+	+	1	1	+	1	+	r	2b	2b	+	+	2a	2a	1-2
d Aptosimum marlothii				+				+		+				+		+		1	r	+		r			+	+	+		2
d Eriocephalus pubescens					+				+						r		1	2b	1		+				2b	1			1-2
d Acacia tortilis																				+	1			r	+	1	1		1
c Nolletia arenosa									+					+						+		+		+		+		+	1
d Hermannia comosa														+										+		+			2
ACACIETOSUM GIRAFFAE *differential species*																													
Acacia giraffae																									1	1	1	+	1
STIPAGROSTION character species																													
Stipagrostis obtusa		3	2a	2a	1	2b	r	1	2a	2a	+	+	3	3	3	3			+	2a	2b	2b	2b	1	+	2a	2a	1	2
Stipagrostis ciliata		1	2b			3		r	2a	+		+		2a	+					2a	+		+	+	r	1	2a	2a	2
Plinthus cryptocarpus					1		r		+	+		+				+												+	2
Intruding species of PENTZIO-CHRYSOCOMION																													
Chrysocoma tenuifolia		r	+	+	r	1	2a	2a		+	1			+	1		1	2a	+		+	+	+	r	+	2a	1	+	1-2
Eragrostis lehmanniana		+			2a	1		+	+	+	+		1	2a	1	+	1	2a	1	1	1	1	+	1	+	1	1	+	2
Aristida congesta							1	3	+	2a		1					+	+	+	+	1			+	+		+		2
Lycium salinicolum								1				+		+			1	+	+						+	+	+	+	2
Gnidia polycephala		+					1	+		+				+				+						+		+	+	+	2
Indigofera alternans										+				+		+		+								+		+	2
Aristida curvata				1			r	+				+													+				1-2
Gazania krebsiana		+												+			+								+		+		2
Aster muricatus														+			+		+										1-2
Schizoglossum capense		+																					+					+	2
Other companion species																													
Tragus berteronianus				r	+	+	+	1			+	+	+	+		+					+		+	+	+	+	+	+	1-2
Phaeoptilum spinosum							1	+		+		+		1			1		+	1	+	+		1				+	2
Dicoma macrocephala								+		+		1		+			+	+	+		+	+	+		+	+			2
Rhigozum trichotomum			3	3					2a		4	3					4		4			4		3				1	2-5
Eragrostis porosa					+			+		+	+	+				+				1	+				1				2
Asparagus suaveolens			+	+								+		1	+							+							2
Polygala leptophylla			+			r		+																	+	+	+		2
Salsola glabrescens			r		+								r		+														2
Barleria rigida								+				+							+						+				2
Pentzia incana												+									+	+					+		1-2
Plinthus karooicus					+			+							+		+												2
Asparagus laricinus									+													+						+	2
Schmidtia pappophoroides																			+		r						+		2
and the species of appendix 7																													

TABLE VI.I.I DIOSPYRION LYCIOIDIS

	Rhoo-Diospyretum																																		
	celtidetosum																																		
																							variant												
Releve number	250	235	223	215	252	207	178	204	199	171	194	165	162	189	156	126	120	122	114	141	101	105	149	118	112	135	106	133	56	35	39	41	42	74	8
Eastern longitude Minutes	20	12	55	49	46	40	38	38	34	33	30	29	27	27	22	21	17	16	13	11	08	08	17	15	10	05	05	03	53	49	48	46	46	40	36
Degrees	27	27	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	25	26	26	26	26	26	26	26	26	25	25	25	25	25	25	25
Southern latitude Minutes	19	30	37	39	39	40	40	40	39	39	38	37	34	35	34	35	35	35	31	31	29	30	35	32	29	31	31	31	37	38	38	39	40	38	35
Degrees	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30
Total species number	15	9	14	12	15	13	9n	13	15	12	10	5	17	10	14	15	15	12	11	12	13	14	10	18	16	17	15	16	13	16	14	13	8	14	14
RHOO-DIOSPYRETUM character and differential species																																			
c Rhus pyroides	2a	2a	2b	2b	2b	2b	4	4	3	4	2b	2a	3	3	3	2b	+	+	3	2a	5	2a	1	2b	3	2b	+	+	2a	1	3	+	2a		+
d Asparagus suaveolens				1	1	2a	1	2a	2a	1	1	+	2b	+	1	+	1	3		+	1	+	1	+	2b	+	+	1	2b	2b	3	1	3	1	2b
d Melica decumbens		1	+		+	2a	+	+	1	+	+		+	3	+	1	1	2b		4		1	1	2a	1	3	1	2b		+		2b			+
c Rubia cordifolia					+	+	+	+			+		+			+				+		1		1		+	+	+		1	1	+		+	
c Bromus willdenowii	1				+			+	+					4		+		1	1	+	+	+	+	+	+		+		r	+		2a			
c Melianthus comosus						1				1	1	1			+	+	+					1		+		1					1				1
c Cineraria lobata				+																							+	1		+	3	+	1			
CELTIDETOSUM differential species																																			
Celtis africana	1	5	4	2a	3	5	3	4	4	2a	2a	4	3	3	2b	4	3	3	+	4	+	1	3	2a	4	3	4	2a	1	+	1	2a		+	r
Achyranthes aspera		+	+		+	+	+	+	1				+		+	+	+	1		1				+	1	+	1	1				2a			
Pentarrhinum insipidum	+	+															+				+											+					
Conyza podocephala	+				+				+							+					+														
Artemisia afra	1		+					+	+								+																		
ZIZIPHO-ACACIETUM KARROO																																			
Acacia karroo																							2b	4	2a	2b	4	4	5	5	5	3		4	3
character and differential species																																			
c Ziziphus mucronata																																			
c Setaria verticillata																																			
c Rhus viminalis																																			r
c Senecio burchellii																																			
c Lycium austrinum																																			
d Viscum rotundifolium																																			
d Schismus barbatus																																			
d Brachiaria marlothii																																			
DIOSPYRION LYCIOIDIS character species																																			
Diospyros lycioides	2a	2b	4	2a	4	2b	2b	3	3	+	2b	2b	3	1	3	4	4	5	1	2a		5	5	4	+	1	2a	+	2a	1	2a	2a	1	2b	3
Lycium hirsutum	1		+	1	1	+		1	1	2a	+		+	1	+	2a	+	2a	1		1	+		1	1	+	+	1		1	+	+	r	2b	1
Lycium arenicolum	+			3	+			+	+	2a	3		+	1	+		+	1	4		1	2a		+	1	1	+	+	1	1		r	5	1	+
Asparagus setaceus	1	+	+	2b	+	+			1	+			+		+	r	+	+	1		2a			+		+	1	1		+	+		+	2b	1
Clematis brachiata				+	+		+	+					+	+	+	r		+		+	+	1		+	+	+		+	r	+	+	+	r	1	+
Atriplex semibaccata	+				+					+	+		+		+		r	+	1	+	2a	+		+	+	+		+	3	1				2a	1
Chenopodium murale						+		+					+		r				+	+	+		+	+	+	+					+			+	
Intruding species of PENTZIO-CHRYSOCOMION																																			
Aster muricatus			+						+	+			+		+	r	r				+			+	+		+				1			3	+
Chrysocoma tenuifolia			+														r					r	r												
Eragrostis lehmanniana	+		+	+															+																
Walafrida saxatilis			+										+																1		r				
Pentzia globosa																									r				+						
Other companion species																																			
Nicotiana glauca						r																													
Hebenstreitia integrifolia																												+							
Salsola glabrescens																																			
Sporobolus fimbriatus			+	+	+																												2a		
Eragrostis porosa																																			
Stipagrostis namaquensis																																			
Silene capensis																											+								

	Rhoo-Diospyretum																	Zizipho-Acacietum																														Sociability
	acacietosum karroo																	karroo																														
Releve number	21	64	30	50	76	6	5	86	308	312	281	315	317	284	288	327	298	301	383	347	382	356	388	359	390	364	377	372	373	415	444	418	420	448	454	427	461	429	482	489	493	516	496	512	502	506	505	
Eastern longitude Minutes	55	55	51	48	40	37	36	34	26	23	23	21	19	18	12	10	02	59	57	48	40	40	38	38	37	37	29	28	24	22	21	20	18	17	14	08	06	05	53	47	46	46	44	42	41	38	37	
Degrees	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	23	23	23	23	23	23	23	23	23	
Southern latitude Minutes	34	35	36	38	39	35	35	37	35	34	33	33	34	34	30	28	21	17	16	06	57	56	54	54	54	54	48	49	47	43	41	39	39	38	37n	36	35	35	20	17	16	12	11	11	08	04	04	
Degrees	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	
Total species number	10	13	11	17	15	14	10	13	14	8	10	11	12	12	10	15	8	9	7	17	12	8	8	8	8	6	9	16	9	12	11	11	14	13	13	11	13	10	7	9	10	13	9	10	5	13	12	
RHOO-DIOSPYRETUM character and differential species																																																
c Rhus pyroides	5	2a	r	+	2a	+	1	1	4	2a	2b	2b	3	3	1	3				2a											1						1					+						1
d Asparagus suaveolens		1	2b	1	2b	2b	+	3	+	1	+	1	1	1	2a	1	1			1	+				+			r									+											2
d Melica decumbens						+			+			+	5	4														+																				2
c Rubia cordifolia	+	+	+																																													1-2
c Bromus willdenowii	2a	3	+	+	1	1	1	+				+																																				2
c Melianthus comosus						2a						1	+							1																												2
c Cineraria lobata	2a		5	r	+			+	+		+		+	+		+				r								1																				1-2
CELTIDETOSUM differential species																																																
Celtis africana																																														1		1
Achyranthes aspera				+																																												2
Pentarrhinum insipidum																+																																1
Conyza podocephala				+																																												2
Artemisia afra																																			+													2
ZIZIPHO-ACACIETUM KARROO																																																
Acacia karroo	+	4	5	4	4	3	2b	4	1	3	2a	4	3	2b	3	3	4	2b	3	2a	4	4	3	3	3	2a	3	4	5	4	4	2a	2b	+	2a	2b	5	2b		3	3	4	2a	2b	2a	5	5	1
character and differential species																																																
c Ziziphus mucronata																	+	3	2a	2b	3	2b	4	4	4	5	2b	2b	1	3	2a	4	3	3	3	4	1	4	2a	1	+	2a	4	2a	4	2b	2a	1
c Setaria verticillata																1			r	2a	4	5	3	1	+		+	4	5	2b	4	4	3	1	+	2a	4	2a	3	2b	2b	2b	3	1	+	+	+	2-4
c Rhus viminalis						r												3	2a	2a		3	1	3			3	2a				3			1						r		2b			+		1
c Senecio burchellii																					+						+	+	+	2a			+		+		2a							+			+	2
c Lycium austrinum																											+	1					1	2a		+		2b										2
d Viscum rotundifolium																				1																		1	+							+		1-2
d Schismus barbatus																																								+		1	+	+				2
d Brachiaria marlothii																																										+		+			+	2
DIOSPYRION LYCIOIDIS character species																																																
Diospyros lycioides	+	2a	2b	2a	2a	1	4	+	1	3	1	2b	3	2b	3	2b	+	2b	2a	1	1	+	2a	+	2b	+	2a	1		+	2a	1	2b	1	1	1	1	2a	4	+	4	1	1	1	2a	1	2b	2
Lycium hirsutum	1	1	2b		+	r	2a	1	2a	1	2b	+	+		+	1	1	1	+	1	2a	1	1	1		1		2a		2b	1	2a	+	1	2a	2a	1	+	2a	1		2a	+	2b		2a		2
Lycium arenicolum	+	2a	r	2a	+	+		+	+	1		2b	+	+	+	+	+	+		+	+	+	+	+	r	+		2a	1	+	+	+	1	1	2a	1	+	1	2a	1	+	2b	+	2a		2a	1	2
Asparagus setaceus	+	+	+		+			+	+	+	1			1	+	+		+			1								+	+	+	+	1	1		+	+	+				+	+			1	+	1-2
Clematis brachiata	+	+	r	+	+	1		+				1		+	+	1	1	1		1	1	1	1		1			1	1	1			+				1				+							1-2
Atriplex semibaccata		2b		5		3	r	2a	+		+	+	+	1	1	1	5				+							1			+		+				1									3		2-4
Chenopodium murale								2a	3		1		+	1	3	1			+	+	+						2a	3	1	+	+	+	+			2b	2a	1										1-2
Intruding species of PENTZIO-CHRYSOCOMION																																																
Aster muricatus							r	1																																								1-2
Chrysocoma tenuifolia				+	+	+			+		r									1																												1-2
Eragrostis lehmanniana																																		+	1													2
Walafrida saxatilis				+																																												1-2
Pentzia globosa		+		1																																												1-2
Other companion species																																																
Nicotiana glauca																								+	+	+															+	+		+	+		+	1-2
Hebenstreitia integrifolia					+				+																			+																				2
Salsola glabrescens				+												+													1							+	c											2
Sporobolus fimbriatus																																																2
Eragrostis porosa																				+												+															+	1-2
Stipagrostis namaquensis																																		+	+												+	2
Silene capensis				+		+																																										2

and the species of appendix 1

TABLE VI.3 HERMANNIO COCCOCARPAE-NESTLERETUM CONFERTAE

	aptosimetosum marlothii													eragrostietosum curvulae																																	oropetietosum																		variant											Sociability
Releve number	542	70	9	277	279	280	282	318	283	321	287	325	326	255	217	212	210	184	181	177	202	180	201	175	196	166	164	163	158	157	155	125	154	124	147	546	555	551	143	113	142	139	134	20	73	307	193	195	191	128	146	540	19	17	24	52	45	40	69	12	78	84	4	1	117	537	100	103	110	60	59	22	68	67	66	
Eastern longitude Minutes	13	41	36	24	23	24	30	19	19	30	14	12	11	51	51	44	43	39	37	37	37	37	36	36	32	28	28	27	25	24	22	20	20	19	16	19	16	13	12	11	10	09	05	56	41	26	30	29	28	23	15	12	57	55	52	50	47	47	43	41	37	34	35	32	12	11	08	07	06	56	56	55	54	53	53	
Degrees	26	25	25	25	25	25	25	25	25	25	25	25	25	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	25	25	25	26	26	26	26	26	26	25	25	25	25	25	25	25	25	25	25	25	25	26	26	26	26	26	25	25	25	25	25	25	
Southern latitude Minutes	27	41	35	36	34	34	35	33	35	30	31	29	27	41	40	33	39	41	41	40	39	41	38	42	38	37	36	36	35	35	36	35	36	34	35	27	30	28	32	29	31	31	32	32	42	36	37	37	34	34	35	27	32	33	34	39	39	37	43	38	40	35	37	36	30	28	29	30	30	33	35	34	35	35	34	
Degrees	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	
Total species number	16	16	8	13	14	13	16	11	18	14	16	10	16	13	16	22	15	16	16	16	16	19	13	17	17	10	12	11	13	18	19	14	16	15	14	19	20	14	12	15	20	23	16	18	19	12	14	11	13	16	14	15	23	19	21	11	13	14	19	9	11	9	17	12	11	11	11	6	9	12	15	5	10	7	7	
HERMANNIO COCCOCARPAE-NESTLERETUM CONFERTAE character and differential species																																																																											
c Cynodon hirsutus																								2b		2a	+	+			1	+	+		+	+			+		+				+	+	+	1					+		+				+	1	+	+														2-3
c Hermannia coccocarpa	+	+																	r					+																+	+			+	1					+	+		+		+	r			+		+	+								+						1-2
c Osteospermum scariosum	1													+		+	r					r					r	r		r							+	+			r	+	r				+		r		+																									1
c Convolvulus boedeckerianus																r		r									r													+		+						+					+		r							+	r	+					+							1-2
d Lessertia pauciflora	+	r											+																			+	r				+	r		+				r						r																				r				+	1
c Nestlera conferta																										2a					+												+	+						1	+		2b			+														+					1	2
c Schizoglossum capense					+			+	+																															r		+								r															+											2
APTOSIMETOSUM MARLOTHII differential species																																																																											
Aptosimum marlothii			+	+	+	+		+	+	+	+	+	+																																																	r														2
Enneapogon brachystachyus	+	+	1	2a		+	+			+	+	+	+																																																															2
Eriocephalus spinescens				+			2a		1		2a	1																																1										1					+												+					1-2
ERAGROSTIETOSUM CURVULAE differential species																																																																											
Eragrostis curvula															1	3	1	+		+	+		+	1		+	+	1	+	+	+	1		+		+	+	+	+			+		1	+	+																												r		2
Cyperus usitatus														1		+	+	+	2a	+		+	+	1	+	+		+	+	+	+	+	1	2a	1					1	+	+	+																																	1-2
Themeda triandra															1	1				+	+		+	+					1	+		1					2a				2a	2b		3									+	1	1															2b			+			2
Helichrysum dregeanum															+	+			+			+	+		+					+						+					+	+			+	+				r	r																						r			2
Solanum supinum															+	+			+												+					+				r		+			r																															2
OROPETIETOSUM differential species																																																																											
Oropetium capense		r																																																	+								+	+	1		+													2
PENTZIO-CHRYSOCOMION species																																																																											
Chrysocoma tenuifolia	2b	2a	1	+	2a	2b	1	2b	2a	3	1	2b		2a	3	1	2a	2b	2a	3	2a	1	2a	2a	2b	1	2b	2a	2b	3	3	3	2a	2a	2b	2a	1	2a	2a	2a	2b	2b	2b	4	3	3	2b	4	2b	2b	2a	2a	2b	3	1	2a	2b	2a	2a	3	2a	3	2a	3	2b	2a	2a		3	2a	3	1	2b	3	2b	1-2
Tragus koelerioides	1	+		+	+	1	+	r	+	+	+	+	+	2a	1		2a	+	1	+	1	1	2a	+	+	r	+		+	+	+	1	+	+		+	1	1	+	+		+	1	2a	1	+	+	+	+	+	1	1	1	1	2a	+	2a	2a	1		+			1		1	1			2a	1		+	1	3	1-3
Eragrostis lehmanniana	1	+	1		1	1	+	r	+	+	+	+	2b	1	+	+	1	+	2a	2a	1	1	+	+	1		1	+	1	2a	1		2b	2a	+	+	+	+		3	2a	1	2a		+		2a	1	2a			1		+	+	2a	+	1	1	+	1	1	1	1	2b	2b	2b	3	3	2b	2b	3	3	2b	2b	2
Pentzia globosa	+	1	3	2a			+	+	2a	r				1	2a	2a	+	2a	2a	1	+	2a	2a	2a	1	2b	+	+	2a	+	2a	1	2a	2b	2a	2b	2a	2b	+	2a	2a	1	2a	2b	3		1	+	2a	1	+	+	2a	+	1	2a	+		1	2a	2b			1	1	1	2a		+		1		+	+	2a	1-2
Walafrida saxatilis	1	+			+	+		+	+	1			+	1	+	1	+	+	+	+	+	+	+	+	+	r	+	r		+	+		+	+	+	1	+		+	+	1	1	+	1	+		+	+	+	+	+	+	+	+	r	+		+	+	1		+	1	1	+	+	1		+	+	1	+	+	1		1-2
Aristida congesta	1	+		+	1	+	+			+	+	+	+	+	2a	1	+	+		+	+	+	+	2a	+	+		+		+	+	3	1				1	+	+	+	+				+	+	2a	r	1		+	+	+	2a			+		+		r	+		1	+	+	r	1	+		+		+		1	2
Eragrostis obtusa	2a						+			+					+	+	+		1			+		+						+	+	1	+	+		1	2b	1	1		+	+	+	+	2a	+			+	+			+	+					1		1	2a		+						2a				1		2
Lycium salinicolum	+	+	1	+		+	+		+	+	+	+		+		+	+			+	+										+				1	1	1		+				+	1	+	+	+	2a	+	+		1		r	1	r			1		+															2
Gnidia polycephala	+		1					+	+				+					+			+	+			+				+	+													+				+	+			+	r				+						+	2a	+	1	+	+				+					2
Indigofera alternans					r	+		+	+		+	+							+			+												+			+	+		+	+	+			+							+	+	+	+			+				+				+	+			+	+					2
Gazania krebsiana		+		+	+		+		+	+	+					+			+											+			+									+				+				+				r	r		r	r	+			+		+						1						2
Aster muricatus														+			+	+		+				+	+					+					+	+	+	+								2a							+		1		+			+		2b										2b				1-2
Pterothrix spinescens									+				1					+			1	+			1				+	+											+								+					+				1					2b		+	+	+		+		+					1-2
Hermannia linearifolia		1									+							+		+		+											+																+	r																										1-2
Mariscus capensis																								1							+									2a							+																					+	1							1-2
Companion species																																																																											
Aristida diffusa							1		+					+	+						1	+			+			+	2a		+			+																1	+						1	2a		+								+					+			2
Nenax microphylla								r						+			1		1		1				+				1				+									+	1					+			1				+			1	1									r				+					2
Limeum aethiopicum	+			+	r						+											r					r									+			r			+	+	+	+	r				+					1																					2
Aptosimum depressum		+				+												+	+	+																							+	+									1	+		r	+	+			r	r				+					+					2-3
Hibiscus marlothianus					+	+	+		+																															+		+											r	+	1		+								+											2
Trichodiadema pomeridianum																									+							+	+	1			+			+		+													1				1																	1-2
Hibiscus pusillus																+														+	+	+		+							r										+		+	+																						1-2
Sutera atropurpurea										+					1			+				+	+							+			+										1								+		1																							1-2
Salsola glabrescens	+		1										r							+																							+									+				1						2a														2
Melolobium microphyllum																					+																				+			+							+		1	r	+										+						1					1-2
Sporobolus fimbriatus																															1					+	+	+						+									+		1				+																	2
Talinum caffrum																											r																			+																+								r						1-2
Helichrysum ericaefolium									+		+																														+													r					1																	2
Enneapogon scoparius																																																				+																								2
Geigeria filifolia		r											+																									+													+						r																			2
Berkheya pinnatifida																+																													+	+									+				+																	2
Asparagus laricinus				+																+	+																										+	+																												2
Asparagus suaveolens										+																+									+									+																																2
Blepharis integrifolia																+	+		+	+																																																								2
Ifloga caespitosa																						+													+						+																													+						1-2
Fingeruthia africana				+																																						+															1																			2
Helichrysum niveum																	+								+								+	+																																										2

and the species of appendix 3