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A west-east vegetation transect through Africa south of the Tropic of Capricorn

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ABSTRACT

Changes in predominant vegetation physiognomy, prominent species and physiography along the route following an 1 800 km transect across southern Africa near the Tropic of Capricorn, are described. Eleven main discontinuities in the structure and floristic composition of the vegetation along the transect are related to a climatic gradient across the Continent. Floristic variation within the main structural types is largely related to rainfall, severity of frost, soil conditions, exposure, slope and aspect. The main vegetation classes distinguished coincide largely with major differences in carrying capacity of the vegetation.

INTRODUCTION

Southern Africa is mainly a fairly flat, high plateau rising steeply from a narrow coastal strip. These topographical features, together with the cool and warm ocean currents flowing on the west and east coasts respectively, have a strong bearing upon the climate and consequently upon the vegetation of the area. Although in climate the western coastal strip differs markedly from the eastern one, both are strongly oceanic, whereas the plateau is distinctly continental. On the plateau, the climate also changes markedly in the west-east direction. Obviously, these climatic and physiographic differences influence floristic composition and structure of the vegetation.

On a general scale close correlations between climatic features, such as precipitation, temperature and humidity on the one hand and differences in physiognomy and prominent species of the vegetation on the other, may be expected. In order to establish these correlations an 1 800 km transect was taken across the continent 1° 30′ to 4° south of the tropic of Capricorn, starting in the coastal Namib desert in the west and proceeding through the steppes, grasslands, savannas and woodlands of the plateau, down to the tropical dense woodlands near the east coast.

The path of the transect shown in Figs. 1–12 was followed by road and conspicuous changes in predominant physiognomy, prominent species and physiography noted. Physiognomic features recorded were cover, height and dominant growth forms of the different strata.

The physiognomic-floristic vegetation classes thus distinguished were related to climatic features recorded in the literature, to topographic maps and to physiographic features recorded along the transect. Habitat features which were related to more detailed variations within the vegetation classes described here were obtained from reports of local studies.

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TOPOGRAPHY

Approximately seven-eights of the 1 800 km transect across the continent passes through the interior plateau and the western and eastern escarpment zones, all of which are above 920 m altitude (Figs. 1 and 2). The altitude decreases rapidly below 920 m to sea level over a distance of 80 km in the west and over 130 km in the east. The western escarpment and the central interior plateau attain 1 560 m and are separated by a low, virtually flat area of the western interior, 380 km wide and approximately 925 m above sea level. The eastern interior plateau lies between 925 and 1 250 m. The highest altitudes are on the eastern escarpment which rises to 2 350 m above sea level.

CLIMATE

The climates according to Köppen's classification (Fig. 3) are arid over the larger part of the transect with the exception of a temperate rainy region (Cwa and Cwb) occurring in the eastern escarpment zone and a tropical rainy region (Aw) along the east coast (Schulze, 1947). Several arid climatic types are traversed, the main division being between the desert climates, occurring west of a line crossing the transect at approximately 700 km from the west coast, and the Steppe climates occurring east of this line. A narrow zone along the west coast, stretching approximately 40 km inland, is classified as BWk or BWkn′. The latter is cold desert with frequent fog and with the mean temperature of the hottest month exceeding 18 °C. Further inland, but still west of the escarpment, the climate (BWh) is hot and dry with the mean annual temperature exceeding 18 °C. As shown in Fig. 4 the region west of the western escarpment falls within the winter rainfall area. The western escarpment and western interior plateau kave a cooler desert climate and fall)within the summer rainfall area (BWkw′). The remainder of the transect also has summer rainfall. The upper, central interior plateau (Fig. 1) falls in the régime of a cold and dry steppe climate, but with the mean temperature of the hottest month exceeding 18 °C (BSkw′). The lower part of the eastern interior plateau and a larger part of the area east of the eastern escarpment have a hot and dry steppe climate, classified as BShw (Figs. 1 and 3).

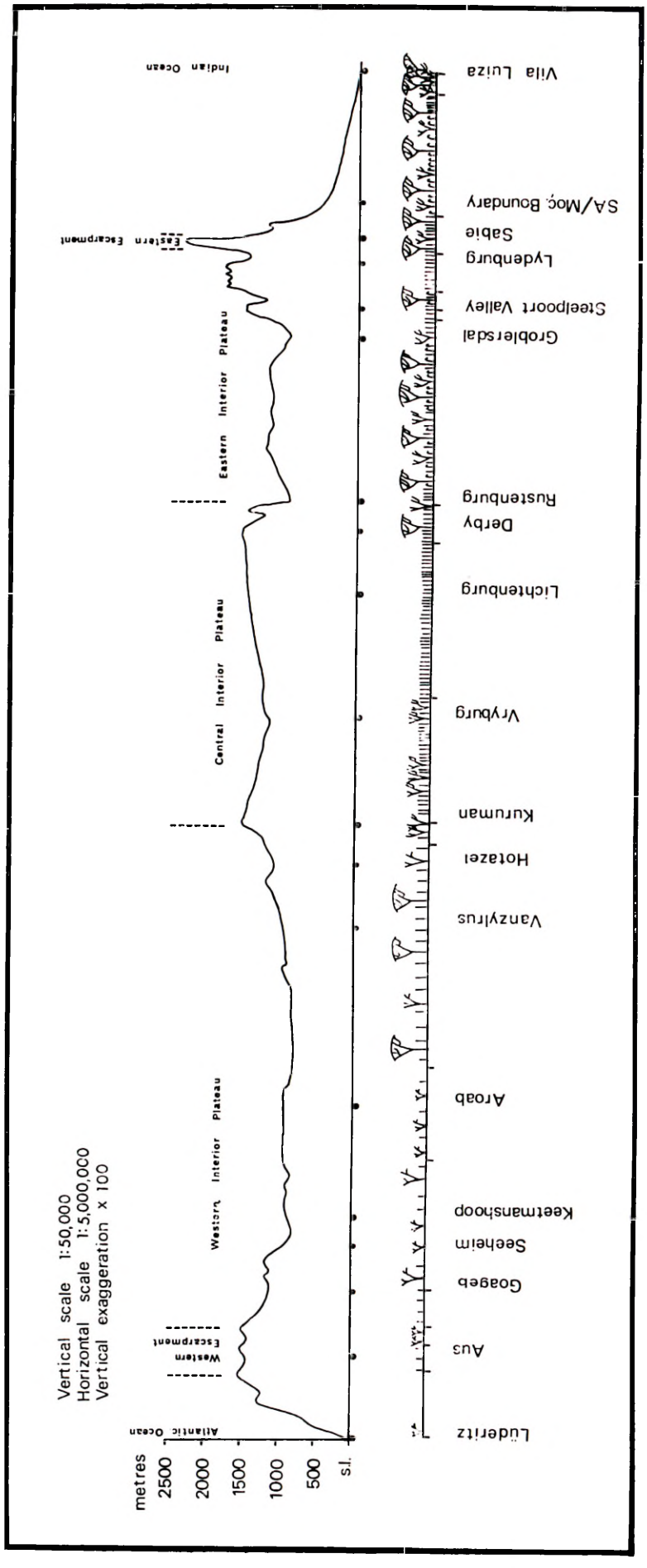

FIG. 1.—Structural changes in the vegetation and altitudinal profile along the transect from Lüderitz to Vila Luiza.

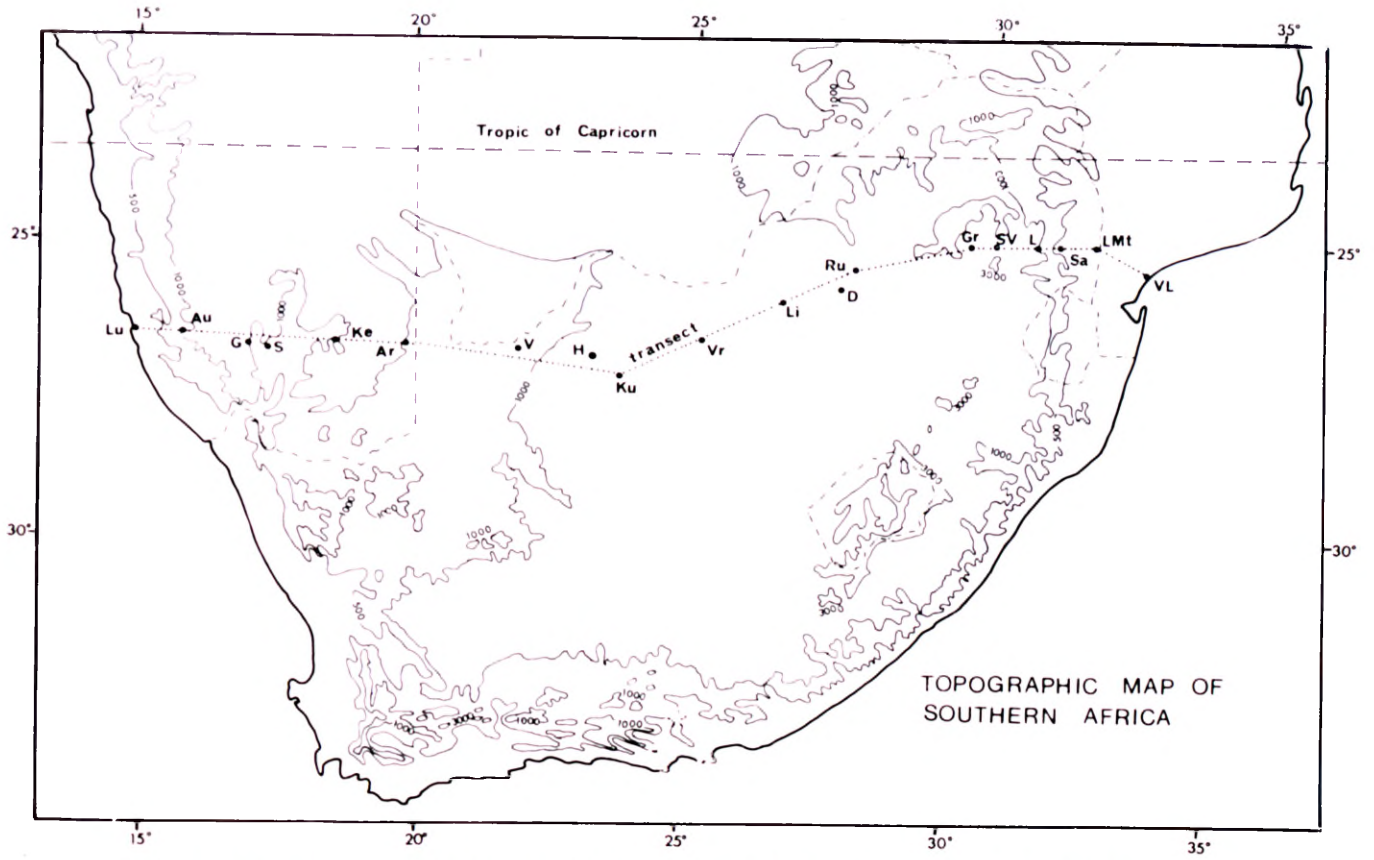

FIG. 2.—Topographic map of southern Africa (see Fig. 1 for place names abbreviated in Figs. 2–12).

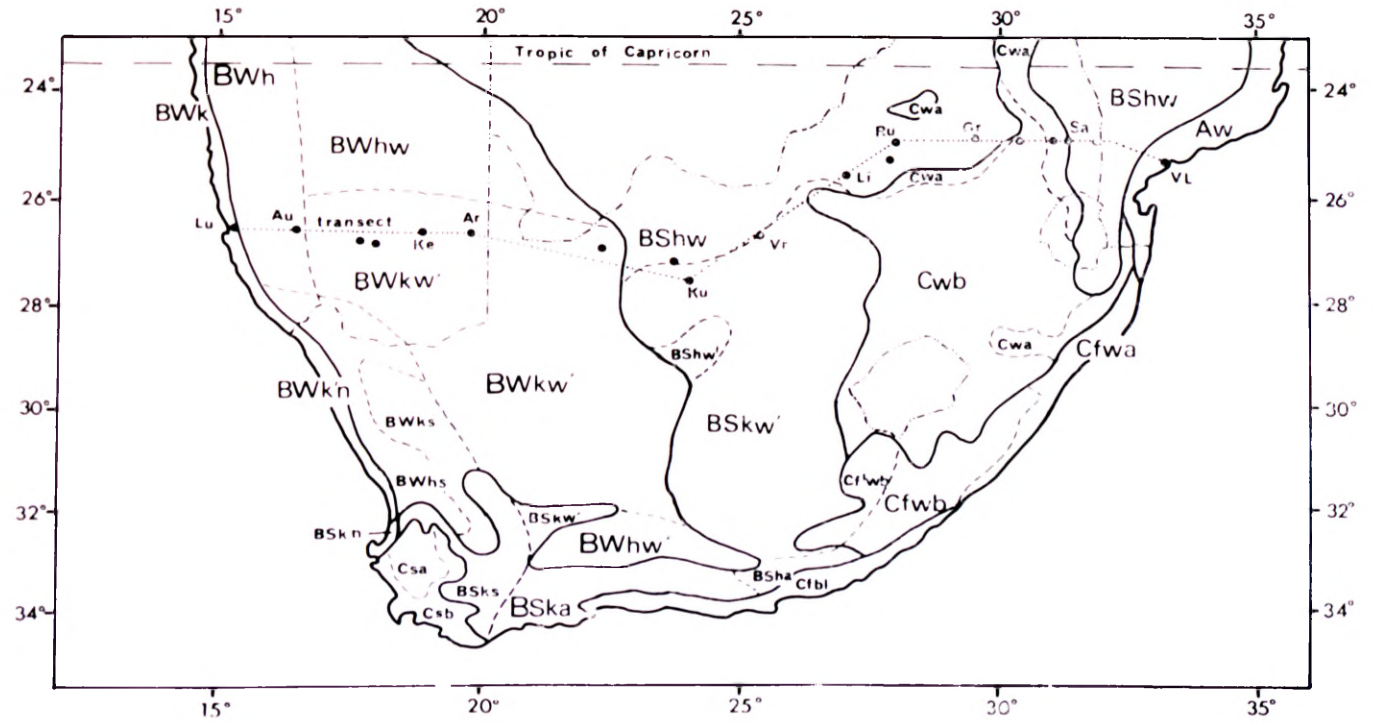

FIG. 3.—Climates of southern Africa according to the Köppen System (from Schulze, 1947).

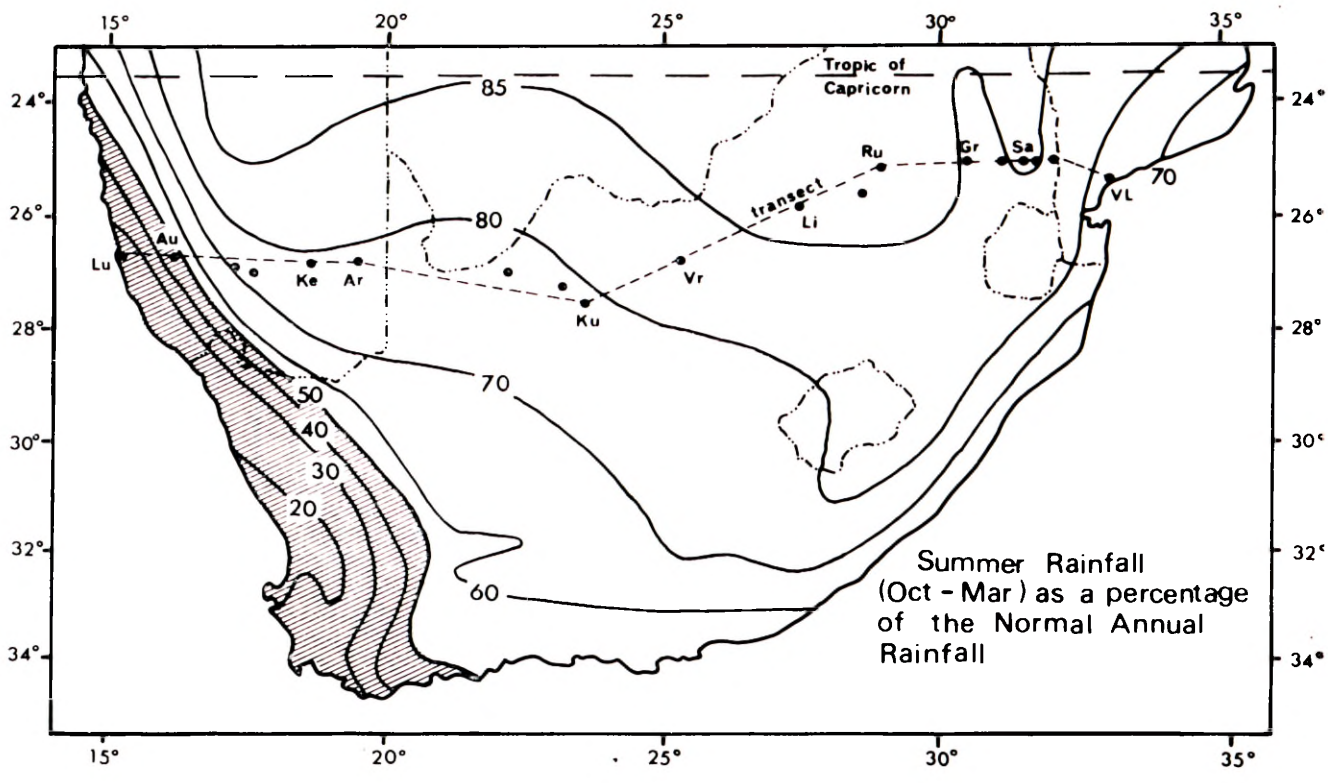

FIG. 4.—Winter rainfall (shaded) and summer rainfall areas of southern Africa (from Weather Bureau, 1957).

Fig. 5 shows that the percentage number of years with frost increase rapidly from the coastal regions (less than 25 per cent) towards the escarpments (100 per cent). Virtually the whole of the interior plateau has frost occurring with greater or lesser severity every year. Schulze (1965) divided southern Africa into a number of regions, based on the temperature régime over the country. From this work it may be seen that the lowest minimum temperatures along the transect occur on the upper parts of the interior plateau between Van Zylsrust and Derby and between Groblersdal and the eastern escarpment. The low temperatures that occur in a narrow zone along the eastern escarpment are not shown in Fig. 6. As shown in Fig. 6, absolute minimum temperatures over most of the interior plateau between Keetmanshoop and Derby are between —5 °C and —10 °C. Frost is less severe west of Keetmanshoop and north-east of Derby (excluding the eastern escarpment region) and frost-free zones occur on the lowlands bordering the east and west coasts. Differences in frequency and severity of frost between the Rustenburg–Groblersdal area of the interior plateau on the one hand and the lowland east of the high escarpment on the other, mark an important distinction between these two hot and dry steppe regions (BShw).

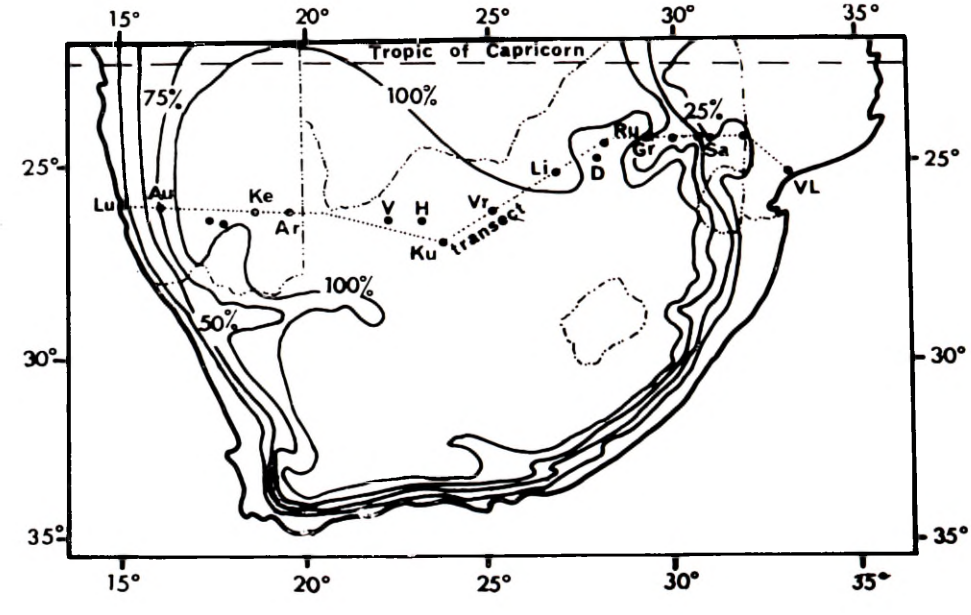

FIG. 5.—Percentage number of years with frost (minimum temperature less than 0° C) (from Schulze, 1965).

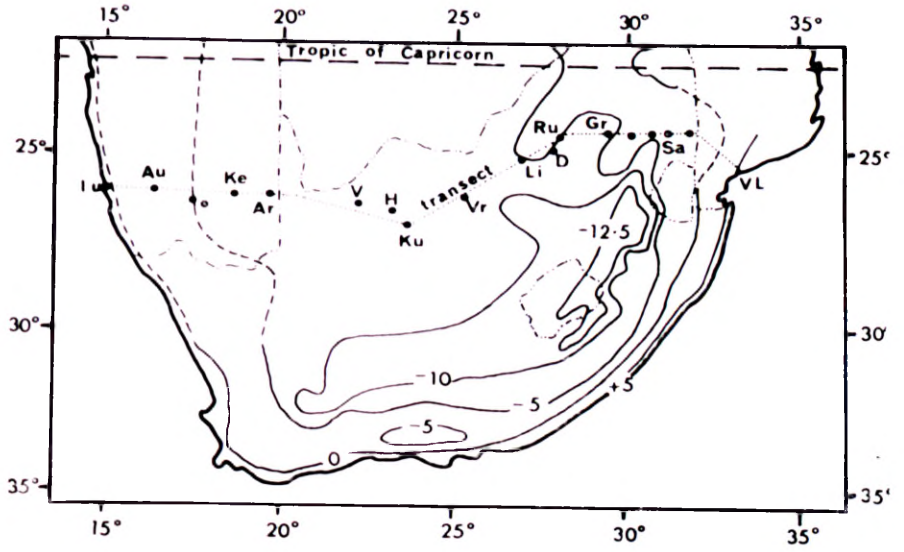

FIG. 6.—Absolute minimum temperatures (°C) in southern Africa (from Schulze, 1965).

Mean daily maximum temperatures of the hottest month (Fig. 7), show an inverse pattern to that of frequency of frost and absolute minimum temperatures. Mean daily maximum temperatures in January are highest in the interior plateau areas where frost is most severe and frequent, and they decrease rapidly as one descends towards the coast. Mean daily maximum temperatures for January near the east coast exceed 20 °C and are higher than along the west coast where this figure is 12,5 °C. These temperatures exceed 27,5 °C over most of the interior plateau (Fig. 7), and absolute maximum temperatures exceed or approach 40 °C over the entire transect (Fig. 8).

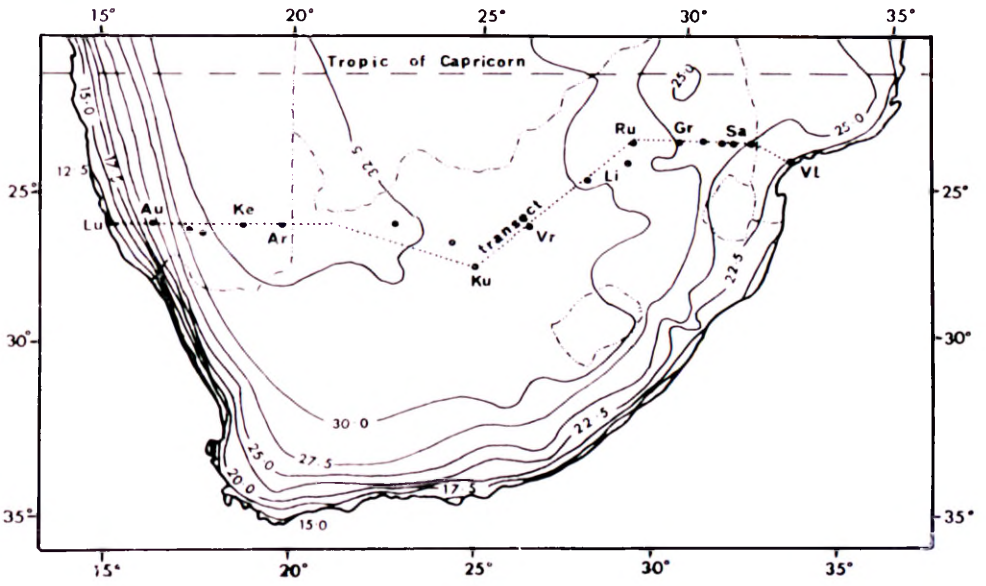

FIG. 7.—Mean daily maximum temperatures (°C) for the warmest month (January) in southern Africa (from Jackson, 1961).

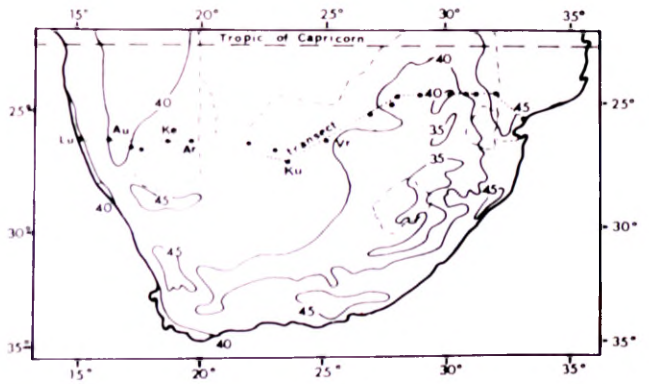

FIG. 8.—Absolute maximum temperatures (°C) in southern Africa (from Schulze, 1965).

The normal annual rainfall of the desert regions between the west coast and escarpment is less than 100 mm (Fig. 9). It increases gradually from 100 mm on the western escarpment to 200 mm near the eastern boundary of the desert climatic types, including the western interior plateau. The reliability of the rainfall, expressed as the deviation from the average annual rainfall (Fig. 10), decreases rapidly from the drier parts of the cold steppe region towards the lower rainfall desert areas in the west so that in these more arid regions rainfall not only becomes lower, but is also less reliable. Further eastward the rainfall gradually increases and becomes more reliable. In the easternmost part of the cold steppe region of the upper, central interior plateau and over the hotter steppe climate of the lower, eastern interior plateau

the rainfall is between 600 and 700 mm. Precipitation increases rapidly to approximately 2 000 mm in the temperate rainy area of the eastern escarpment and decreases again to between 600 and 700 mm in the hot steppe lowland region east of the escarpment. Another rapid increase occurs eastward towards the tropical rainy region and the rainfall at the coast is between 1 000 and 1 250 mm.

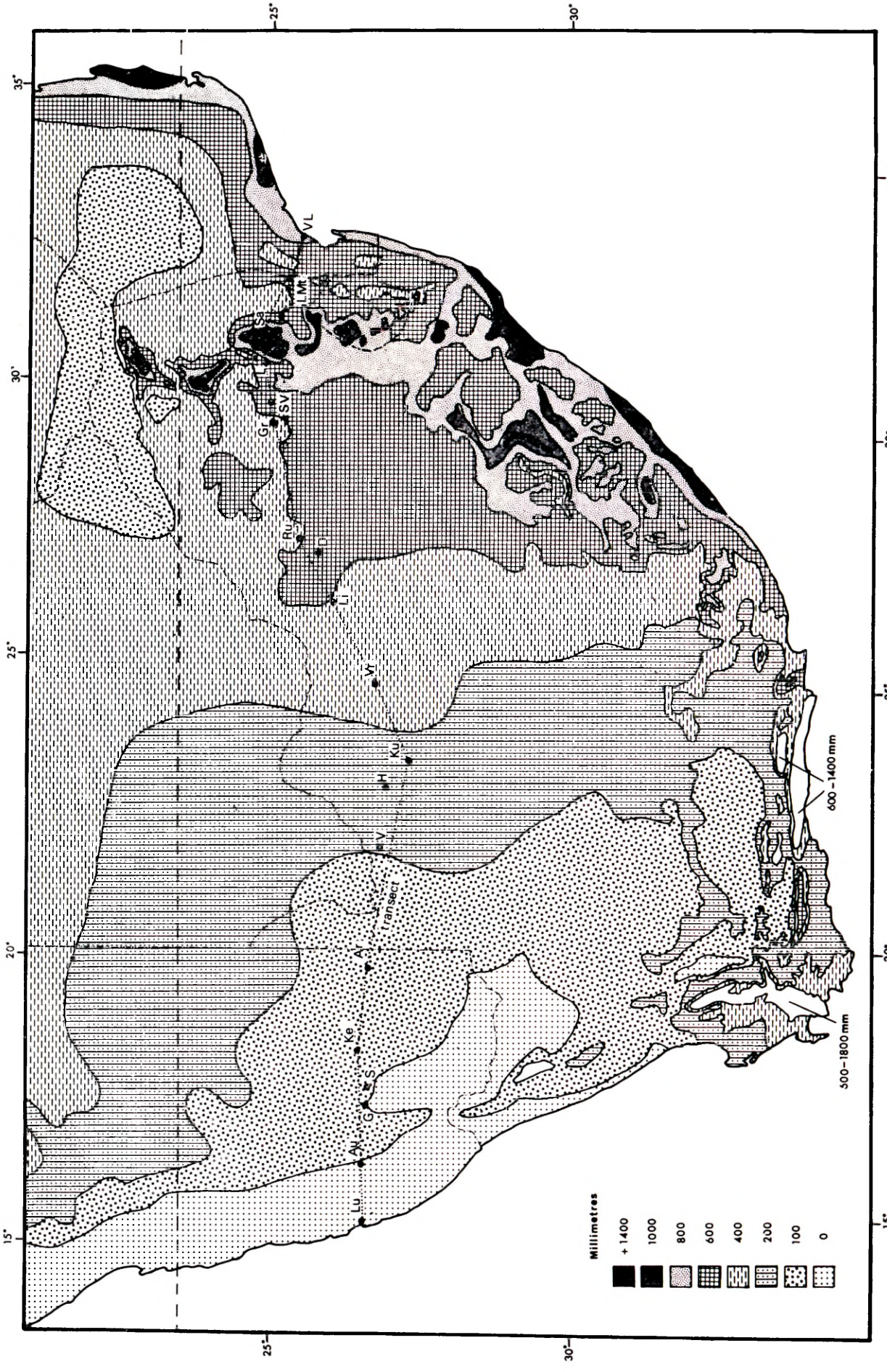

FIG. 9.—Mean annual rainfall in southern Africa (from Jackson, 1961).

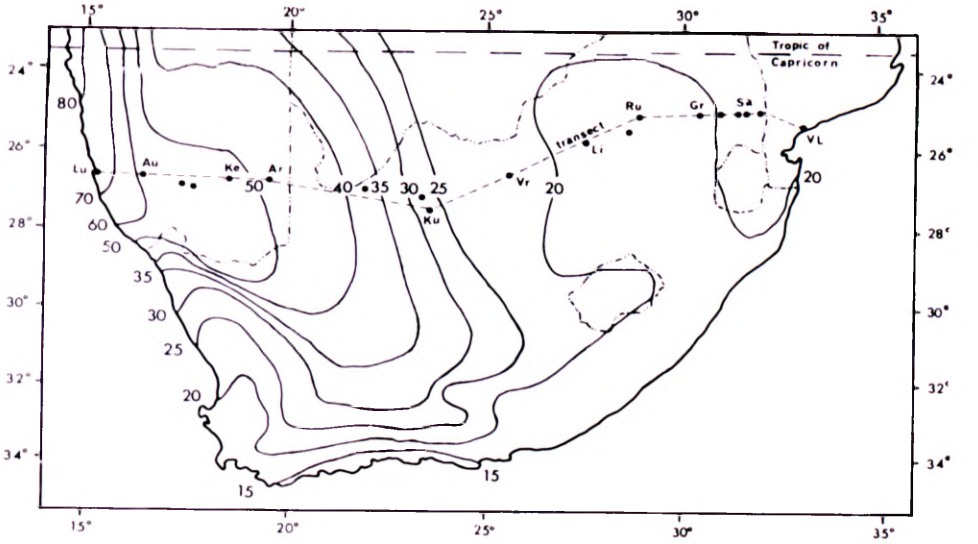

FIG. 10.—Mean deviation as a percentage of the average annual rainfall (from Weather Bureau, 1957).

There is an evident increase in rainfall from the west coast to the east coast in which the effect of altitude above sea level is apparent from local rainfall peaks. Altitude above sea level also influences to a certain extent the occurrence and severity of frosts.

In the desert climatic regions (BW) west of Kuruman, where the rainfall is below 200 mm, all 12 months are dry, as defined by Walter & Lieth (1960). East of this line the number of dry months per year drop to five or six.

Humidity over any part of the transect, including the western dry winter-rainfall area, is higher in midsummer (Fig. 11) than in midwinter (Fig. 12). In summer, as well as in winter, both coastal regions have a higher humidity than the interior and the humidity along the tropical rainy east coast is higher than the humidity of the cooler desert along the west coast at any particular time of the year.

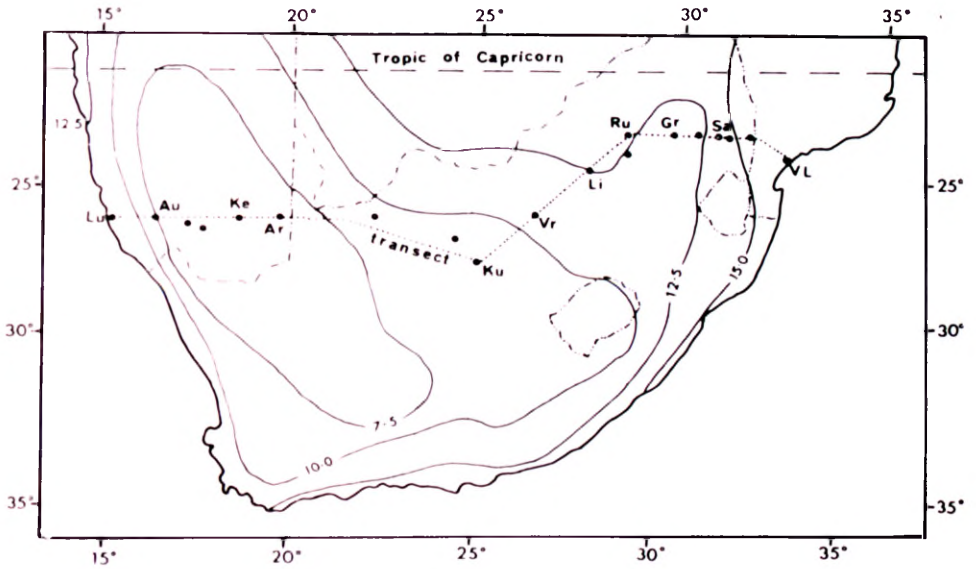

FIG. 11.—Mean humidity mixing ratio for the warmest month (January) in southern Africa (from Jackson, 1961).

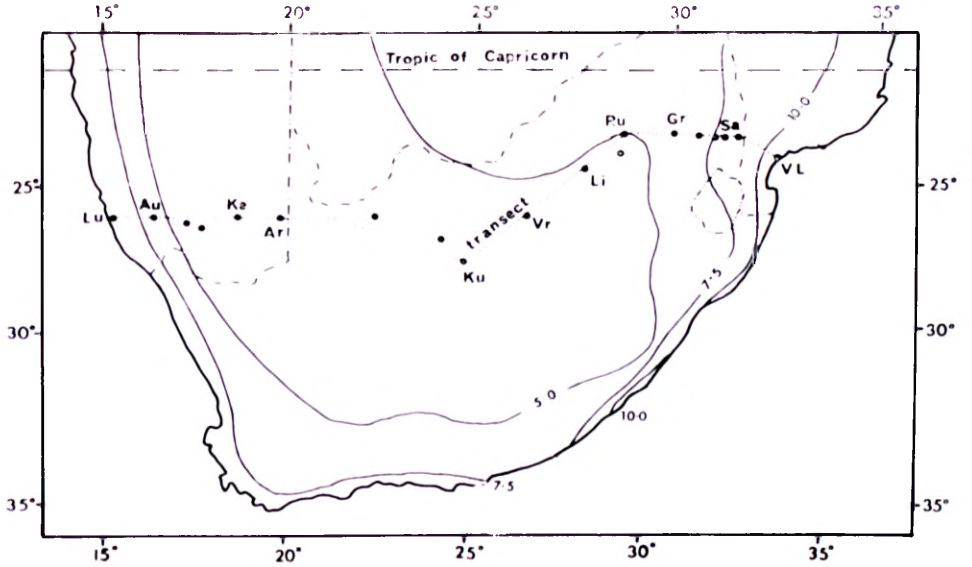

FIG. 12.—Mean humidity Mixing ratio for the coldest month (July) in southern Africa (from Jackson, 1961).

PHYTOGEOGRAPHY

The boundary between the Karoo-Namib Region and the Sudano–Zambezian Region (Volk, 1966; Werger, 1973) largely coincides with the boundary between the desert climatic types (BW) and the steppe climatic types (BS). On the eastern escarpment the transect crosses through narrows bands of the Afro-montane and Austro-afro-alpine Regions (Chapman & White, 1970; White, 1971; Coetzee, 1967). In the tropical rainy area (Aw), near the east coast, the transect crosses through the Usambara-Zululand Domain of the Guineo-Congolian Region (Chapman & White, 1970; White, 1971). All these Regions are part of the African Palaeotropis.

VEGETATION

The true Namib desert extends from Lüderitz for about 100 km inland. Altitude increases from sea level to about 1 250 m over this distance. The vegetation in the Namib is generally extremely sparse. Near the coast, where strong seaward and landward prevailing winds alternate, the desert is a mosaic of deep, coarse sandy patches, with shallow runnels and eroded granitic outcrops. The outcrops are virtually bare, but in the drainage lines a sparse vegetation of dwarf shrubs and xerophytic grasses occurs. Main species are *Salsola aphylla, Psilocaulon marlothii, Drosanthemum floribundum, Osteospermum crassifolium, Lycium decumbens, Sarcocaulon spinosum* and the grass *Eragrostis cyperoides*. Apart from the grass, which is hard and coarse, all species are succulent in either their leaves or their stems. Total cover of this vegetation is below one per cent with plants up to 30 cm tall (Fig. 13).

On dune sand a sparse growth of *Stipagrostis sabulicola,* around which small dunes are formed, occurs locally (cf. Giess, 1962, 1971). On rocky places a few kilometres inland, open stands of the virgate shrub *Lebeckia* sp. are occasionally encountered. Shrubs may be up to 3 m tall and cover less than one per cent. The shrub *Ectadium virgatum* var. *latifolium* with hard, coriaceous leaves, is also found here. Further away from the coast, in the hot, dry desert (BWh), where strong winds and fog gradually decrease, extensive open stands of *Sarcocaulon spinosum*, up to 0,10 m high and covering less than one per cent are found (Fig. 14). On the slopes of the mountains and sometimes on the gravelly plain open stands of

FIG. 13.—Rocky outcrops near Lüderitz showing very sparse vegetation of succulent dwarf shrubs.

FIG. 14.—Extremely open stand of **Sarcocaulon spinosum** in the southern Namib, approximately 20 km from the coast.

FIG. 15.—Southern Namib approximately 70 km inland, entirely bare of vegetation.

the stem succulent *Euphorbia gummifera*, up to 1,5 m in height, occur. About 50 km inland a plain which is absolutely devoid of vegetation, is reached. This is interrupted by occasional very sparsely vegetated mountainous outcrops of coarse, gravelly, reddish sand, which often have a hard surface layer (Fig. 15).

About a hundred kilometres inland, approximately 15 km west of Aus, the Vornamib starts with a low grass steppe of about 5 per cent total aerial cover (Fig. 16). The main species are *Stipagrostis lanipes, S. obtusa, S. ciliata, Ehrharta pusilla* and *Eragrostis nindensis*. *Sarcocaulon spinosum* and *Eriocephalus pubescens* also occur occasionally. The soil consists mainly of a rather coarse, sometimes gravelly sand. Further eastward the shrub *Dyerophytum africanum* becomes locally abundant and grass cover increases to about 8 per cent. *Acacia erioloba* trees start to occur here. Near Aus the total aerial cover of the vegetation which, except for *Stipagrostis* species, now also contains many other herbs, geophytes and dwarf shrubs, has increased to about 15 per cent with local patches reaching 25 per cent. In this vicinity, 120 km inland from Lüderitz, a small, low escarpment brings the general level of the surface to 1 500 m (Fig. 1). The slopes of the escarpment and the isolated mountains are vegetated mainly by dwarf shrubs, about 0,40 m high, covering up to 20 per cent, with isolated small trees of up to 3 m. The plains between the mountains are covered with the 0,25 m high grass steppe vegetation described above. The soil of the plains consists mainly of yellowish and reddish sand. This Vornamib or desert margin vegetation falls within the cooler desert climate (BWkw') with sporadic summer rainfall up to approximately 100 mm, and continues to about 50 km east of Aus, 170 km from Lüderitz. The countryside becomes gradually more rocky with ridges and table mountains covered with dwarf shrub vegetation and the grass-covered plains become more restricted in extent. The dominant grass is now *Stipagrostis ciliata*, which locally covers up to 40 per cent.

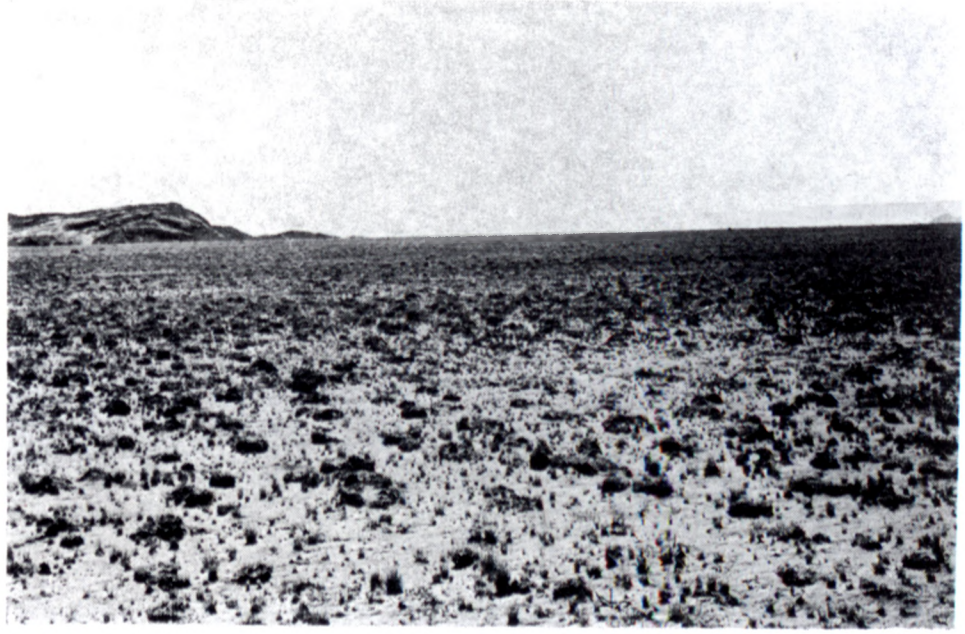

FIG. 16.—Vornamib near Aus showing low grass steppe with mainly **Stipagrostis** spp.

A vegetation type, which Giess (1971) calls dwarf shrub savanna and which differs considerably from the Namib and Vornamib vegetation, starts 170 km inland from Lüderitz. The climate is of the cool desert type with summer rainfall between 100–200 mm. The soil of this plateau area is usually stony or gravelly with stones usually large (about 0,10–0,20 m in diameter and occasionally reaching 0,50m). Calcrete concretions are abundant and sometimes thick layers of calcrete are present. Total cover of the vegetation varies between 10 and 25 per cent (Fig. 17). Dwarf shrubs and shrubs are dominant. Grasses, which otherwise do not cover more than 5 per cent, are more abundant where sandy patches occur. The most important grasses are *Stipagrostis obtusa* and *S. ciliata*. The shrubs *Rhigozum trichotomum* and *Catophractes alexandri*, which are often between 0,40–2 m tall, and the dwarf shrubs *Zygophyllum* cf. *meyeri* and *Z. suffruticosum*, up to 0,50 m high, are dominant in patches which can be up to 5 km in diameter. Shrubs of *Acacia mellifera* subsp. *detinens*, *Phaeoptilum spinosum*, *Boscia foetida* and *Parkinsonia africana* and low trees of *Boscia albitrunca* and *Aloe dichotoma* also occur and can locally cover up to two per cent and reach 2 or 3 m in h ight. Drainage lines are occasionally fringed by open woodlands with trees up to 6 m tall and covering about 15 per cent, mixed with shrubs, up to 4 m tall, which cover 15 to 25 per cent. The tree species are usually *Acacia erioloba*, *Ziziphus mucronata* and *Euclea pseudebenus* and the shrubs predominantly *Acacia mellifera* subsp. *detinens*. Over vast stretches the vegetation described above alternates with open shrubland, in which *Euphorbia gregaria* is completely dominant (Fig. 18). The latter type of vegetation occurs particularly in the vicinity of Goageb, where the rocky plateau is undulating and has an occasional butte rising above it. Where the plains are stone-strewn and rocky they are interrupted by low, slightly raised ridges. The granite and quartzite stones are angular, usually 0,10–0,20 m in diameter and often cover 75 per cent or more of the surface. The soil between these stones is a sandy loam. *Euphorbia gregaria* is a glaucous, leafless, succulent shrub, with a globular form, measuring 1–2 m in diameter. A number of other shrubs occur, of which *Rhigozum trichotomum* is most abundant, but *Phaeoptilum spinosum*, *Acacia mellifera* subsp. *detinens* and some *Boscia* spp. also occur. *Stipagrostis uniplumis* is present although not abundant. The total cover of this vegetation type is almost entirely made up by *Euphorbia gregaria* and varies between 5–20 per cent.

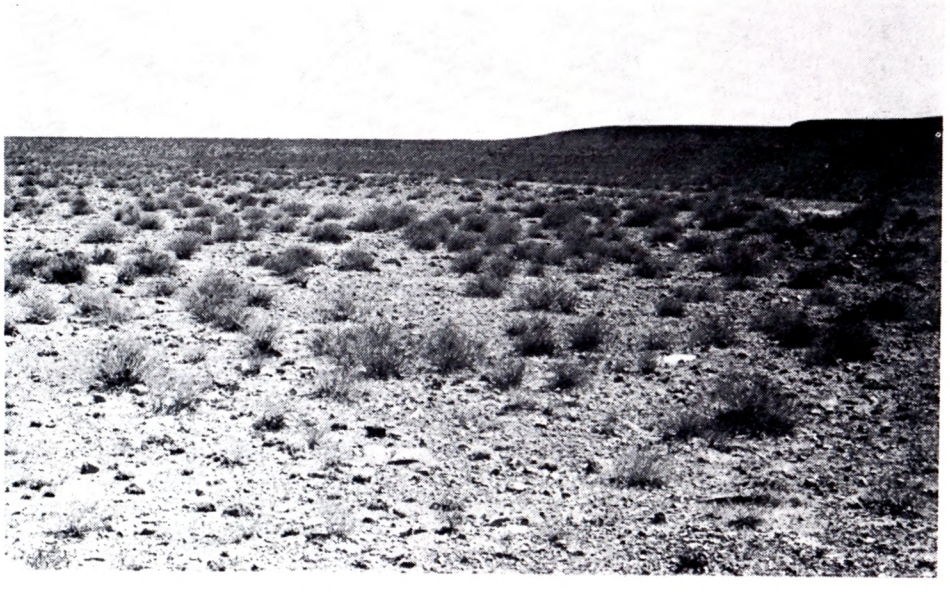

FIG. 17.—Dwarf shrub steppe of mainly **Zygophyllum** spp. on stony soil approximately 60 km east of Aus.

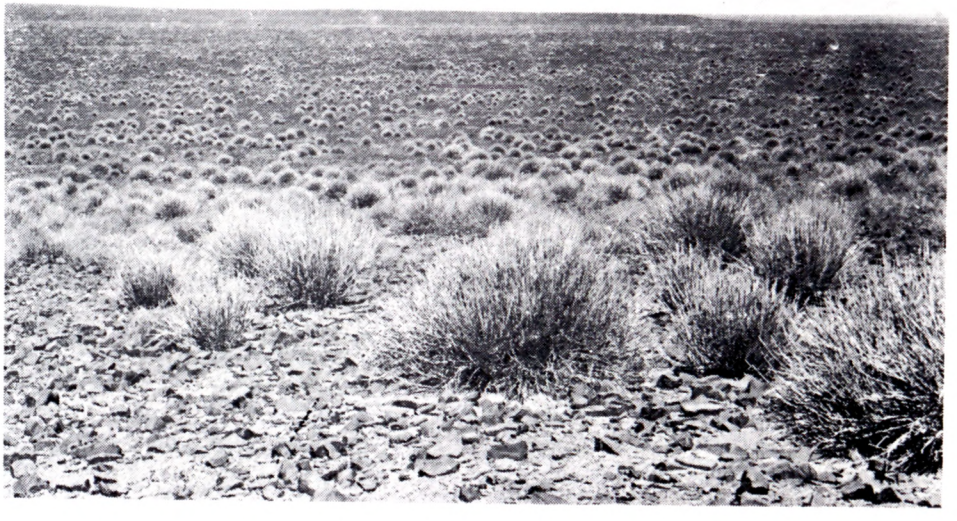

FIG. 18.—Extensive open stand of **Euphorbia gregaria** approximately 80 km west of Keetmanshoop.

Near Seeheim the transect crosses a few shale ridges, on which an open shrub community occurs. The main shrub and low tree species up to 2 m tall, are *Boscia albitrunca, Aloe dichotoma, Cadaba aphylla, Euphorbia virosa, Adenolobus gariepina, Acacia mellifera* subsp. *detinens, Phaeoptilum spinosum* and *Rhigozum trichotomum*. Conspicuous grass species include *Stipagrostis uniplumis, S. hochstetterana* var. *secalina* and *Panicum arbusculum*. Total cover reaches about 20 per cent, of which about 4 per cent is contributed by the grass and dwarf shrub layer.

Towards Keetmanshoop the vegetation over large stretches is an open shrubland with usually a low ground cover. It is a slightly sloping, sometimes undulating plateau covered with a sandy loam, containing fine gravel in places. The shrubs, up to 1,5 m tall and covering about 10–15 per cent and occasionally reaching 25 per cent, are mainly *Rhigozum trichotomum* (dominant), *Parkinsonia africana, Phaeoptilum spinosum, Acacia mellifera* subsp. *detinens, Boscia foetida, Cadaba aphylla, Boscia albitrunca* and *Zygophyllum suffruticosum*. A few small trees of *Pappea capensis* also occur. Grasses are sparse with a total cover of about one per cent, mainly made up by *Stipagrostis uniplumis*. In drainage lines shrub growth is often somewhat more dense and *Acacia erioloba* and *Acacia karroo* occur occasionally. In deep, sandy drainage lines *Stipagrostis namaquensis* is encountered.

shrub steppe, reaching 0,60 m height. The landscape is flat and the soil changes from a rather deep sandy loam to being very shallow with thick calcrete outcrops. Main species include *Salsola tuberculata* and *Zygophyllum dregeanum*, which are dominant in places. *Stipagrostis ciliata, S. uniplumis* and *Enneapogon brachystachyus* are important grasses. Total cover varies between 10–25 per cent. The dwarf shrubs often cover about 10–15 per cent and the grasses 5–10 per cent. In places patches of *Rhigozum trichotomum* are encountered, and low trees of *Boscia albitrunca* are rare. Sometimes this karroid dwarf shrub steppe is interrupted by a pan or a patch of savanna with shrubs up to 3 m tall, but covering only 2 per cent or less. The main shrubs are *Boscia foetida* and *Parkinsonia africana*, but scattered low trees of *Boscia albitrunca* are found. On exposed calcrete, patches of *Catophractes alexandri*, up to 2 m tall and covering about 2 per cent, occur.

About 100 km east of Keetmanshoop, nearly 500 km inland of Lüderitz, this vegetation type of karroid dwarf shrub steppe interrupted by open shrub savanna, comes to an end, when along a very narrow boundary the dune sand area of the southern Kalahari is reached. Although the main climatic conditions do not change, the presence of a thick sand substrate brings about a major change in the vegetation.

For the next 350 km, stabilized red sand dunes dominate the landscape. Sometimes a pan with a surface of very compact, loamy soil or less often calcrete and dry riverbeds, with calcrete or pink to white sandy river banks interrupt the monotony of

FIG. 19.—Open shrub and dwarf shrub vegetation approximately 40 km east of Keetmanshoop with drainage line in middle distance.

About 20 km east of Keetmanshoop the transect crosses some oddly-weathered rocky outcrops on which *Aloe dichotoma* is very abundant. Other shrubs and dwarf shrubs also occur, covering about 5 per cent, as well as an open grass growth in which various *Stipagrostis* spp. and *Panicum arbusculum* are conspicuous. Total cover of this vegetation reaches about 25 per cent. Having passed through these rocky outcrops, the transect runs again on a loamy plain carrying mainly the same open shrub vegetation as in the vicinity of Keetmanshoop (Fig. 19). However, approximately 50 km east of Keetmanshoop, just over 200 km after this open shrub vegetation started, the vegetation changes to an open, karroid dwarf

this area. The vegetation on the sand consists largely of a very open tree or shrub savanna (Fig. 20), although owing to overstocking, denuded areas and drifting dunes occur frequently. On pan surfaces and in dry riverbeds open grassland communities, some entirely ephemeral, are found, and on the calcrete an open dwarf shrub steppe usually occurs. Trees of *Acacia erioloba* and *A. haematoxylon* are most abundant in or near the dry river beds, but can occur throughout the area. The vegetation on the sand usually consists of a catena of two or three communities (cf. Leistner & Werger, 1973). On the red dune tops occurs a community with the tall shrubby, 1,5 m high grass *Stipagrostis amabilis* and the tuft

grasses *Eragrostis lehmanniana, E. trichophora, Asthenatherum glaucum, Aristida meridionalis, Stipagrostis uniplumis, Brachiaria glomerata* and *Schmidtia kalahariensis*. The virgate shrub *Crotalaria spartioides* is also typical of the dune tops. Other woody plants on dune tops include *Acacia erioloba, A. haematoxylon* and *Boscia albitrunca* that are up to 6 m high. Several shrub *Lebeckia linearifolia* occur in the river bed, although the latter also occurs on the sand dunes. Other frequently-encountered plants in the river beds include *Geigeria pectidea, Amaranthus dinteri, Psoralea obtusifolia, Platycarpha carlinoides, Panicum impeditum, Deverra aphylla* and several others (cf. Leistner & Werger, 1973). Large trees of *Acacia*

FIG. 20.—Dune country in the southern Kalahari showing open tree savanna of **Acacia erioloba** with tall tufts of **Stipagrostis amabilis** on dune crests.

other annual and perennial forbs and dwarf shrubs occur on dune tops as well as in dune valleys, including *Acanthosicyos naudinianus, Citrullus lanatus, Chascanum pumilum, Oxygonum* spp., *Limeum* spp., *Hermannia* spp. and *Tribulus zeyheri*. Total aerial cover usually varies between 5–15 per cent, but can be nearly zero in heavily grazed areas.

In the dune valleys *Asthenatherum glaucum* is particularly abundant. Other frequently encountered species include *Crotalaria sphaerocarpa, Hirpicium echinus, Dicoma schinzii, Stipagrostis uniplumis, Acanthosicyos naudinianus, Eragrostis lehmanniana, Brachiaria glomerata, Schmidtia kalaharensis, Gisekia africana* and *Limeum sulcatum*. Total cover of this vegetation varies between 10–25 per cent. Trees and shrubs are less common than on dune crests, but *Acacia haematoxylon, A. erioloba* and *Grewia flava* are regularly encountered, although they usually cover less than one per cent.

In deeper dune valleys, where a calcrete layer comes close to the surface and the sand is of a pinkish colour, a community with more dwarf shrubs and low shrubs up to 1,20 m in height, covering about 10–15 per cent, occurs. Common species include *Monechma incanum, Aptosimum albomarginatum, Indigofera alternans, Chrysocoma polygalifolia, Stipagrostis ciliata* and particularly *Rhigozum trichotomum*. A similar community is found on the pink sand dunes fringing some of the dry riverbeds and pans, but *Acacia mellifera* subsp. *detinens, Grewia flava, Acacia erioloba, Boscia albitrunca* and *Lycium austrinum* are more common here. The trees are up to 6 m tall and the total aerial cover usually varies between 10 and 15 per cent. In the dry river beds *Stipagrostis obtusa* and *Rhigozum trichotomum* frequently dominate alternately on white sandy fringes, whereas in the clayey central part *Panicum coloratum, Chloris virgata, Geigeria pectidea, Enneapogon brachystachyus* and others are locally dominant. Often the dwarf shrub *Galenia secunda* and the *erioloba* and *A. haematoxylon* are also found and under these trees *Setaria verticillata* is usually dominant.

Where the river is fringed by calcrete banks, an open dwarf shrub community, up to about 0,60 m tall, and with an aerial cover between 5 and 15 per cent, is found. Important plants on these calcrete banks include *Aizoon schellenbergii, Barleria rigida, Zygophyllum pubescens, Sylitra biflora, Indigofera auricoma, Enneapogon scaber, Rhigozum trichotomum* and *Stipagrostis obtusa*. Sometimes a few individuals of *Boscia albitrunca* and *Lycium austrinum* are encountered. In pans extensive stands of the annual grass *Sporobolus coromandelianus* or the perennial *Sporobolus rangei* can be seen. Cover in these stands can vary greatly, but it is seldom more than 30 per cent.

Near Hotazel, about 850 km from Lüderitz, where the precipitation reaches 300 mm, the Kalahari ends. This boundary is, however, not as sharp as where the Kalahari started, 350 km further westward. Even as far as 100 km before the Kalahari ends, in the vicinity of Van Zylsrus, at the 200 mm isohyet, the vegetation starts to change gradually. Trees and shrubs gradually play a more important role in the landscape. *Acacia haematoxylon, A. mellifera* subsp. *detinens* and *Boscia albitrunca* are the most common trees. They are up to 4 m tall and cover up to 30 per cent of the surface. *Rhigozum trichotomum* is locally also important. Grasses cover about 20–25 per cent. On dune crests *Terminalia sericea* is now the most common tree, being 3 to 6 m tall and covering up to 20 per cent.

About 50 km west of Hotazel the first rocky outcrops occur, which carry a vegetation with shrubs and grasses. In the sandy areas total cover gradually increases and can reach values of about 40 per cent.

In this vegetation type, shrubs, which are mainly *Rhigozum trichotomum, Lycium tenue, Acacia mellifera* subsp. *detinens* and *Grewia flava*, and the trees *Boscia albitrunca* and *Acacia erioloba*, vary in cover between 5 and 20 per cent. The trees are up to 7 m tall. Dwarf shrubs, particularly *Gnidia polycephala*, and grasses, such as *Eragrostis lehmanniana, Stipagrostis uniplumis, S. ciliata* and *S. obtusa*, often cover about 25 per cent.

Near Hotazel the dune sand starts to disappear from the landscape and the surface rises to the upper, central plateau (Fig. 1). The climate changes from a desert type to a cold, dry steppe climate (BSkw'), with a summer rainfall of over 300 mm. In the shrub layer *Tarchonanthus camphoratus* becomes more important. East of this area the "white" grasses (mainly *Stipagrostis*) of the Karoo-Namib Region are rapidly replaced by "purple" grasses of the Sudano-Zambezian Region.

Apart from local sandy patches, the soil in the area between Hotazel and Kuruman, a distance of about 50 km, is usually shallow, loamy sand, and very stony. The landscape is mainly slightly undulating, regularly interrupted by mountainous ridges. The vegetation consists of an open to a fairly dense shrub savanna. The shrubs are 1 – 3 m tall, covering between 5 and 35 per cent. The most important shrubby species are *Rhigozum trichotomum, Rhigozum obovatum, Acacia haematoxylon, A. hebeclada* var. *stolonifera, A. mellifera* subsp. *detinens, Euclea ovata, Grewia flava* and, in particular, *Tarchonanthus camphoratus*. Occasional low trees of *Boscia albitrunca* occur and where the soil consists of somewhat deeper sand the shrub layer is sparse and trees of *Acacia erioloba*, covering 1–2 per cent, are present. In open patches, grasses and herbs cover up to 25 per cent, but usually their contribution is lower. Common grasses include *Anthephora pubescens, Themeda triandra, Heteropogon contortus, Eragrostis lehmanniana, Aristida congesta* and *Rhynchelytrum repens*. Total cover values vary between 25 and 40 per cent.

At Kuruman, where the rainfall reaches 400 mm, the Ghaap Plateau starts. The Plateau is a vast flat plain of calcrete and dolomite, extending eastwards over a distance of 170 km to beyond Vryburg (cf. Mostert, 1967). This plateau vegetation is classified by Acocks (1953) as Kalahari Thornveld, together with the vegetation of the southern Kalahari, although they represent different subtypes. The vegetation on the Ghaap Plateau alternates from nearly pure grassland to a dense shrub savanna. Where the calcrete or dolomite is overlain by a thin layer of reddish Kalahari sand, grasslands occur (Fig. 21). The grasses, which are up to 1 m high, reach total cover values of 60 or 80 per cent. The most important species are *Eragrostis lehmanniana, Themeda triandra, Chrysopogon montanus, Cymbopogon plurinodis, Heteropogon contortus, Digitaria eriantha, Sporobolus fimbriatus, Aristida curvata, A. congesta, A. diffusa* var. *burkei, Enneapogon brachystachyus* and several others. Where calcrete or dolomite is exposed on the surface, shrubby patches occur which are usually dominated by *Tarchonanthus camphoratus* with or without *Grewia flava*, but other woody species, such as *Acacia mellifera* subsp. *detinens, A. karroo, Rhus lancea, R. ciliata* and occasionally *Boscia albitrunca* occur as well. *Acacia erioloba* sometimes occurs as polycorms on deeper sand. These woody species are usually 1–2 m, or occasionally up to 4 m high and cover between 5 and 40 per cent. Total cover in this shrub savanna is up to 80 per cent.

About 25 km east of Vryburg, more than 1 000 km inland from Lüderitz, an important boundary is reached. Agricultural cultivation becomes possible here and soon becomes one of the main forms of land use. West of this boundary, agricultural practices are confined to natural-pasture management except for the true Namib desert where the carrying capacity is too low. Where this boundary is reached the climate is still of the BSkw' type, but the rainfall has increased to 500 mm. Near Lichtenburg, about 160 km east-northeast of Vryburg, at the 600 mm isohyet, the climate changes to a hot and dry steppe climate (BShw), but the general features of the landscape remain the same. The landscape is a flat to gently undulating grassy plain, which extends about 250 km in an east-northeast direction along the transect (Fig. 22). The soil is sometimes deep and ploughed, other times shallow and rocky, with calcrete and dolomite outcrops. Pans occur regularly. The vegetation consists of almost pure grasslands, which in the western and central parts are interrupted by occasional thornbush savannas. The grasses are tufted and about 1 m tall, with cover values of 70–80 per cent. The species composition changes as the precipitation increases from 500 mm in the west to 700 mm in the east. In the same direction the grass cover also become somewhat

FIG. 21.—Grasslands on Ghaap Plateau, approximately 15 km east of Kuruman. In the background a patch of shrub savanna dominated by **Tarchonanthus camphoratus** is visible.

denser. In the drier western part of this central plateau grass land, which falls in Acocks's (1953) Dry *Cymbopogon-Themeda* Veld, species with xerophytic characteristics are prevalent (Roberts *et al.*, 1972). The most conspicuous species are *Stipagrostis uniplumis, Eragrostis lehmanniana, Anthephora pubescens, Cymbopogon plurinodis* and *Themeda triandra.* A mixture of species with low nutritive value during all but the earlier part of the growing season, called sour grasses, parts, was found by Morris (1973) and Morris & Guillerm (1974) to be most strongly related to position on the gently undulating surface. In the eastern parts in the Central Variation of Acocks's Bankenveld, where the topography is more strongly rolling, Coetzee (1974) found exposure, slope, aspect and pedological characteristics to be important factors related to variation in species composition.

FIG. 22.—Grasslands of the eastern part of the central plateau with open woody vegetation on outcrops in the distance.

is characteristic of the higher rainfall area, and predominate in the central and eastern parts. These parts fall in Acocks's Sandy *Cymbopogon-Themeda* Veld and Bankenveld respectively. Notable among these sour grasses are *Trachypogon spicatus, Sporobolus pectinatus, Loudetia simplex, Eragrostis racemosa, Cymbopogon excavatus* and *Diheteropogon amplectens.*

The patches of thornbush savanna in the western parts of this grassland plateau consist of an open to fairly dense tree and shrub layer, up to 5 m in height, with cover values of at least 15 per cent, and a grassy understorey. Total cover values of this vegetation type are often between 60 and 80 per cent. The main woody species include *Acacia mellifera* subsp. *detinens, A. hebeclada* var. *stolonifera, A. tortilis, A. erioloba* and *A. karroo*, but *Tarchonanthus camphoratus, Grewia flava, Ziziphus mucronata, Ehretia rigida, Rhus ciliata, Rhus pyriodes* and *Rhus lancea* also occur. Over most of these western and central parts of the plateau area, however, woody plants are absent, probably as a result of particularly severe frosts that occur on 60–90 days per annum (Acocks, 1953; Roberts *et al.*, 1972, Fig. 5 and 6). *Acacia caffra* and *Protea caffra* savannas with a grassy understorey occur regularly on low ridges and hillsides in the eastern parts. Acocks (1953) considers regular burning to be an important factor in maintaining a predominantly grassy vegetation here. It is only east of the Ghaap Plateau that the cover of the vegetation becomes sufficiently dense to allow fires on an extensive scale.

Local variation in floristic composition in the grasslands in the Lichtenburg area, which is on the transition from the drier western to the wetter central

Immediately north-west of Derby, just over 100 km east-northeast of Lichtenburg and more than 1 250 km from Lüderitz, the landscape changes abruptly. The gently undulating grassland gives way within less than one kilometre to hilly terrain with grassy and shrubby savannas and woodlands on hillsides and denser woodland in valley bottoms. Frost occurs regularly in winter, but is less severe than on the slightly higher and more exposed grassland plains to the south. The rainfall is as high as on the adjoining grassland plains and the climate is still classified as BShw. The tree canopy, covering 20–30 per cent, is between 3 and 8 m tall and is dominated by *Rhus lancea, Acacia karroo, Olea africana* and *Acacia robusta.* A fairly dense woodland of *Rhus lancea, Buddleia saligna, Olea africana* and *Ziziphus mucronata*, 5–8 m tall and with a total aerial cover of 75 per cent, is typical of the valley bottoms. Several shrub species form a middle stratum and the grass cover ranges from 50 per cent in the denser woodland to 95 per cent in the more open savannas on slopes. The grasses are up to 1,5 m tall. Dominant grasses on hotter, west-facing slopes include *Themeda triandra, Cymbopogon plurinodis* and *Heteropogon contortus* while *Setaria lindenbergiana* is dominant on mesic south-facing slopes. This vegetation type, which falls in Acocks's Sourish Mixed Bushveld, occurs as an irregular belt on the foothills and gentle slopes fringing mountains and highlands and is crossed for about 20 km by the transect.

The vegetation on the Magaliesberg, which is encountered south-west of Rustenburg, about 1 300 km from Lüderitz, and where the rainfall is between 700 and 800 mm, is together with the rest of the

mountain vegetation in the northern and north-western Transvaal classified by Acocks (1953) as Sour Bushveld. Several communities have been described by Coetzee (1975) from a small area near Rustenburg on this narrow mountain range. Forest communities occur in kloofs with tree species up to about 13 m high and with interlocking canopies. These forests include *Ilex mitis, Pittosporum viridiflorum, Rothmannia capensis, Bequaertiodendron magalismontanum, Mimusops zeyheri, Celtis africana* and *Ficus pretoriae* as common canopy trees. The predominant vegetation types of the south- to west-facing mountain slopes are deciduous *Acacia caffra* savannas with trees up to 8 m tall and evergreen *Protea caffra* savannas in which the trees are up to 5 m tall. Tree cover in both savanna types is between 15 and 60 per cent (Fig. 23). *Protea caffra* savannas also occur on top of the mountain where the vegetation is mainly dense sour grassland and open shrubland. Prominent species in the grasslands include *Themeda triandra, Trachypogon spicatus, Eragrostis racemosa, Diheteropogon amplectens, Rhynchelytrum setifolium, Brachiaria serrata, Loudetia simplex, Tristachya biseriata* and many other grasses and forbs, most of which also occur in the grass layers of the *Protea caffra* savannas. The shrublands, which are up to 3 m tall, are confined to broken rocky outcrops and are characterized by *Bequaertiodendron magalismontanum* and *Landolphia capensis*. On extremely shallow litholic soils, a large number of small plants with xerophytic characters is found, including the desiccation-tolerant *Myrothamnus flabellifolius, Selaginella dregei* and *Oropetium capense* and a number of succulents including *Euphorbia schinzii, Adromischus umbraticola, Frithia pulchra, Khadia acutipetala, Anacampseros subvelutinum* and *Euphorbia clavarioides*. North- and east-facing slopes of the mountain are dominated by deciduous savannas and woodlands with *Burkea africana, Faurea saligna, Combretum zeyheri, Acacia caffra* and several other woody species. The trees are up to 10 m tall and cover between 30 and 60 per cent. Shrubs and a dense grass layer form the under-storeys. *Setaria perennis, S. lindenbergiana, Heteropogon contortus, Trachypogon spicatus* and *Tristachya biseriata* are dominant grasses in these deciduous woody vegetation types. Variation in the vegetation of a northern and southern kloof of the Magaliesberg have been described by Van Vuuren & Van der Schijff (1970) who conclude from the species composition on the two sides of the mountain that it forms a clear climatic and floristic boundary.

The landscape between Rustenburg and Groblersdal, a distance of 220 km, where the rainfall is again between 600 and 700 mm and the frost less severe than south of the Magaliesberg, is mainly flat to undulating with a number of distinct savanna and woodland vegetation types that are related to soil and topographic differences. Considerable parts of this vegetation have been severely disturbed by townships, horticulture, removal of trees and overgrazing. The grasses are a mixture of sour and sweet types, sweet grasses being those that retain their nutritive value well into the dry season. A grassy woodland of *Faurea saligna* and *Burkea africana*, in which the tree canopy is up to 9 m tall and covers 20 per cent, with an understorey of tall grasses of up to 1,5 m high, covering about 60 per cent, occurs in a flat narrow belt of coarse sandy soil, fringing the Magaliesberg on the northern side. The dominant grasses are *Eragrostis* spp. and *Digitaria* spp. (Fig. 24).

FIG. 23.—**Acacia caffra** and **Protea caffra** Savannas on the Magaliesberg near Rustenburg.

Further to the north-east, on the same flats but on black clay soils derived from norite, about 10 km of thornbush savanna occurs. The savanna is dominated by 3–8 m tall thorny microphyllous trees of *Acacia tortilis* and *A. karroo* with 15 per cent cover, occasional shrubs and a dense grass layer forming the undergrowth. In relatively well preserved stands of this vegetation type the grass cover is 95 per cent and up to 1 m tall, with *Themeda triandra, Elionurus argenteus, Aristida* spp. and *Heteropogon contortus* as dominants. South-facing and north-facing slopes of a long range of norite hills, which protrude from the flats and run parallel to the Magaliesberg differ

FIG. 24.—**Burkea africana** Savanna on sandy soil in the Waterberg area (Photo: J. P. H. Acocks).

considerably in species composition. A woody vegetation of *Acacia caffra* and many other low tree and shrub species occurs on the south-facing slopes of these hills. The woody species range between 1 and 5 metres in height with cover varying from 15 to 60 per cent. The grasses are 1 m tall, cover 60–70 per cent and include *Themeda triandra, Eragrostis* spp., *Setaria lindenbergiana, Heteropogon contortus, Rhynchelytrum setifolium* and *Elionurus argenteus*. The north-facing slopes carry a shrubby woodland vegetation with up to 7 m tall trees covering 60 per cent and a grass cover of 75 per cent. *Combretum molle* and *Pouzolzia hypoleuca* are among the dominants, but many more woody species are common. The dominant grasses, up to 1,5 m tall, are *Heteropogon contortus* and *Setaria lindenbergiana*.

In the undulating landscape to the north-east of where the transect crosses the norite hills, the vegetation belongs to Acocks's Sourish Mixed Bushveld and Mixed Bushveld. A broad-leaved deciduous *Combretum apiculatum* savanna occurs on the coarse, gravelly and sandy soils of the convex upper parts of the undulations (Fig. 25). A mixture of several other woody species contributes to the 25 per cent total cover of the upper stratum, which is 3–8 m tall. Shrubs up to 3 m tall can cover approximately 10 per cent. Grass cover varies between 30 and 90 per cent and dominant grasses are up to 1,5 m tall. In this savanna, clumps of dense woodland with diameters of about 10 m, are found on termite nests where the soil is more loamy and moisture and aeration conditions differ from those of the surroundings. Dominant woody species in such dense clumps include *Dicrostachys cinerea, Acacia tortilis, A. nilotica, Rhus leptodictya* and *Ziziphus mucronata*. The first three species are listed by Grunow (1965) among the prominent plants of woodland communities occurring on sandy loam topsoils underlain by sandy clay, within the Sourish Mixed Bushveld. Microphyllous thornbush dominated by *Acacia mellifera* subsp. *detinens*, with a dense grassy understorey, grows in the clayey lower parts of undulations (Fig. 26). The shrubs are between 3 and 5 m tall and cover up to 80 per cent and *Panicum maximum*, the dominant grass in a 1,5 m tall stratum, covers 80–90 per cent in some places. A savanna vegetation with *Sclerocarya caffra, Terminalia sericea, Combretum apiculatum, Acacia nilotica, A. tortilis, Dicrostachys cinerea* and *Euclea undulata* among the prominent trees and shrubs, is found on flat areas with red sandy-loam soil (Fig. 27). The tree stratum includes trees from 2–8 m tall and covers 25 per cent, the shrub stratum ranges from 0,5–2 m, and covers 2 per cent and the grass and forb stratum, which reaches up to one metre, covers approximately 60 per cent. In a detailed study of a small area within Acocks's Sourish Mixed Bushveld, Grunow (1965) found differences in soil to be the most important factors related to the occurrence of various communities.

About 100 km east-north-east of Rustenburg lies an isolated flat area of 20 by 40 km covered by deep, reddish-brown Kalahari sand with a distinctive vegetation. The vegetation is a 7 m tall savanna with trees covering 25 per cent. Shrubs, between 1 and 2 m tall, also cover 25 per cent. The grass layer is 1 m high, covering 80 per cent. Dominant trees and shrubs include *Acacia erioloba, Mundulea sericea, Acacia luederitzii* var. *retinens, Boscia albitrunca, Terminalia sericea, Grewia flava* and *Tarchonanthus camphoratus*, which differentiate this vegetation from that of surrounding areas. *Panicum maximum, Eragrostis rigidior* and *Digitaria* spp. are among the dominant grasses. This sandy vegetation has been classified by Acocks as Kalahari Thornveld.

The short, steep climb from Groblersdal eastward through hilly terrain, passes through shrubby savanna with many tree and shrub species, including *Terminalia sericea, Combretum zeyheri, Peltophorum africanum, Acacia nilotica, Sclerocarya caffra, Dicrostachys cinerea, Dombeya rotundifolia, Acacia tortilis, Pterocarpus rotundifolius* and several others. *Dombeya rotundifolia* and *Croton gratissimus* are conspicuous trees and shrubs of the savannas on rocky outcrops. On hillsides a savanna is encountered in which *Faurea saligna, Diplorrhynchus condylocarpon, Burkea africana, Acacia caffra, Pterocarpus rotundifolius, Combretum zeyheri, Vitex* sp. and *Ozoroa* sp. are among the predominant woody species. *Burkea africana* savanna occurs on deeper soils near the summits. The woody species in these savanna types reach heights of up to 6 m and cover about 30 per cent. These vegetation types fall in Acocks's Sourish Mixed Bushveld. From a small area 40 km to the south of the transect and in a similar part of this Veld Type, Theron (1973) described a number of communities in which slope, aspect, altitude, geology, soil texture and soil depth were among the habitat features that are related to the variation in vegetation.

FIG. 25.—**Combretum apiculatum** Savanna in Mixed Bushveld near Jericho.

FIG. 26. — Microphyllous thornbush dominated by **Acacia mellifera** subsp. **detinens** near Jericho.

FIG. 27.—Savanna vegetation on red sandy-loam soil in the Sourish-mixed Bushveld near Hammanskraal.

Dense, sour grassland predominates over the 15 km of undulating plateau in the temperate rainy region (Cwb) west of the Steelpoort Valley. This grassland is similar in structure and related in prominent species to the grasslands of the moister parts of the upper interior plateau, crossed by the transect between Lichtenburg and Rustenburg and found on top of the Magaliesberg. The rainfall is between 700 and 800 mm and soils are coarse and sandy. Dominant grasses include *Urelytrum squarrosum, Themeda triandra, Schizachyrium sanguineum, Eragrostis chloromelas, Elionurus argenteus, Setaria perennis, Tristachya rehmannii, Trachypogon spicatus, Eragrostis racemosa, Panicum natalense, Perotis patens, Heteropogon contortus* and *Cymbopogon excavatus*. On granitic outcrops the vegetation is a shrubby savanna of *Acacia caffra, Combretum molle, Dombeya rotundifolia, Canthium gilfillani, Bequaertiodendron magalismontanum* and several others, all of which are common in the Sour Bushveld of the Magaliesberg. The vegetation on this plateau is classified by Acocks as North-Eastern Sandy Highveld.

On the slopes of the Steelpoort Valley, 40 km east of Groblersdal, the vegetation consists of a shrubby savanna with a large variety of woody species, including *Terminalia prunioides, Rhus engleri, Euclea undulata* var. *myrtina, Grewia vernicosa, Cassine transvaalensis, C. aethiopica, Boscia albitrunca, Croton menyhartii, Acacia gerrardii, Ormocarpum trichocarpum, Croton gratissimus* var. *gratissimus, Kirkia wilmsii, Vepris reflexa, Mundulea sericea, Strychnos madagascariensis, Commiphora angolensis* and *Pavetta tristis*. Most of these species clearly differentiate the vegetation of this hot dry valley, which receives 500–600 mm precipitation annually, from the cooler moister savanna and woodland regions to the west and east. A savanna dominated by *Acacia tortilis, Terminalia prunioides, Boscia foetida* subsp. *foetida* and patches of the low shrub *Euclea linearis* occurs on the 2 km wide, flat valley floor.

East of the Steelpoort Valley a vegetation type similar to that encountered west of the valley continues for another 40 km. Further eastward the topography changes to a strongly rolling and mountainous country, with savannas on rocky hillsides and otherwise sour dense grasslands, which belong to the Eastern Variation of Acocks's (1953) Bankenveld. The rainfall of this 20 km wide isolated patch of Bankenveld is between 600 and 700 mm. Many of the dominant woody species and grasses are the same as those found in the higher rainfall parts of the central interior plateau, the Sour Bushveld of the Magaliesberg and the rest of the north-eastern mountain plateau.

The ascent over 25 km eastwards to the edge of the Drakensberg escarpment passes through Acocks's North-Eastern Mountain Sourveld. The topography is undulating to rolling, rising in altitude to 2 350 m. Mean annual precipitation is between 700 mm in the west and 1 750 mm or more on the escarpment. The area is subject to severe frosts. Here the transect crosses through a vegetation with a strong Afromontane element and a considerable Austro-afroalpine element in the flora. Van der Schijff & Schoonraad (1971), in a study of the escarpment 50 km to the north of the transect, list a number of characteristic sour grasses, geophytes, forbs and dwarf shrubs for the typical dense mesophytic grassland of this region, including the large tussocky *Merxmuellera drakensbergensis,* and *Eragrostis sclerantha, E. caesia, E. capensis, Agrostis barbuligera* var. *longipilosa, Harpechloa falx, Loudetia simplex, Watsonia densiflora, Moraea spathulata, Helichrysum* spp., *Erica drakensbergensis, Protea gaguedi, Vaccinium exul, Restio sieberi* var. *schoenoides* and *Tetraria cuspidata*. From the highest region of the escarpment the altitude drops within a few kilometres down steep mountain slopes to Sabie where the woodlands of the Eastern Transvaal Lowveld start. The climate of these slopes is classified by Schulze (1947) as Cwa. These escarpment slopes are covered mainly by grassland and tree plantations. Small trees, shrubs and ferns, including the tree fern *Cyathea dregei*, occur in small moist sheltered kloofs. Dense indigenous evergreen montane forest occurs patchily in deep kloofs and extensively on mesic south-east-facing slopes of the eastern escarpment (Fig. 28). Van der Schijff & Schoonraad (1971) distinguished four strata in well developed parts of this forest. The upper tree stratum of up to 18,0 m includes *Podocarpus latifolius, P. falcatus, Cussonia umbellifera, Ochna oconnorii, Curtisia dentata, Kigellaria africana Nuxia floribunda, N. congesta, Apodytes dimidiata* and several others Other strata are a lower shade-tolerant tree stratum, a shrub stratum and a herbaceous stratum. The cover of the latter two strata varies considerably, depending on aspect and amount of light penetrating the higher strata. The rainfall in such kloofs at Mariepskop to the north is according to Van der Schijff & Schoonraad (1971) possibly up to 2 500 mm per annum.

FIG. 28.—Dense montane kloof forest on the eastern escarpment with **Ensete ventricosum** in foreground (Photo: J. C. Scheepers).

The area between the escarpment and the east coast is practically frost free except for some occasional frosts occurring along rivers (Van der Schijff, 1957, 1969). The climate of this lowveld area is, except for the narrow coastal belt, classified as a hot and dry steppe climate (BShw), but the belt next to the escarpment has a higher rainfall than the central plateau area. Over the first 40 km to the east of the escarpment the landscape is hilly and rolling to undulating with sandy soils and rainfall decreasing

from 1 000 mm in the west at the bottom of the escarpment, to 700 mm in the east. The vegetation belongs to Acocks's Lowveld Sour Bushveld. It is a savanna or woodland with *Terminalia sericea* among the dominant woody species. Other common woody species are *Sclerocarya caffra, Albizia versicolor, Dichrostachys cinerea, Combretum molle, Pterocarpus angolensis* and others. Evergreen trees, including *Trichilia emetica,* which are found only along river banks on the drier flats to the east, are common in this higher rainfall area (Van der Schijff, 1969). Shrubs and sour grasses largely make up the understoreys. Woody species are up to about 8 m tall although they are usually shorter and cover generally between 20 and 60 per cent.

The 90 km-wide area eastward to the South African border on the Lebombo Mountains has a mean annual rainfall of 600–700 mm. The western 60 km of this area is an undulating granitic terrain with sandy soils and has mainly a deciduous broad-leaved savanna, dominated by *Combretum apiculatum* with shrubs and grasses in the understorey. Large termite mounds of the genus *Macrotermes* are common in this savanna, the old ones carrying a specific community, among which *Diospyros mespiliformis, Schotia brachypetala, Ziziphus mucronata, Spirostachys africana* and *Xanthocercis zambesiaca* are typical. A denser woodland of microphyllous thorny species including several *Acacia* species, *Dichrostachys cinerea* and *Spirostachys africana* occurs on clayey soils between the rises. On dolerite dykes an *Acacia nigrescens* woodland, which is up to 10 m high, occurs (Van der Schijff, 1957, 1969). A savanna, dominated by *Acacia nigrescens* and *Sclerocarya caffra* and including *Combretum imberbe* and *Lonchocarpus capassa,* occurs on the heavy basaltic soils of the flats immediately west of the Lebombo Mountains (Fig. 29). The trees are up to 10 m high and usually cover up to about 25 per cent. The dominant grasses in the ground layer are sweet and include *Panicum* and *Digitaria* species. Total aerial cover amounts to about 60 or 70 per cent. On the rhyolitic, litholitic soils of the Lebombo Mountains a savanna dominated by *Combretum apiculatum* with several other woody species including *Pterocarpus rotundifolius* is found. The woody species are up to 4 m tall and total cover of the vegetation amounts to about 60 per cent. On ridges and in kloofs the woody species are denser and include *Diospyros mespiliformis, Terminalia phanerophlebia, Antidesma venosum, Afzelia quanzensis, Euphorbia confinalis, E. cooperi, Ficus ingens, Androstachys johnsonii* and others (Van der Schijff, 1957; Gomes Pedro & Grandvaux Barbosa, 1955). On the undulating terrain with basaltic soils, east of the Lebombo Mountains, the *Acacia nigrescens-Sclerocarya caffra* savanna, occurs again over a stretch of about 40 km. Further eastward the annual rainfall increases to approximately 900 mm. The soil is sandy and carries a broad-leaved savanna or woodland similar to the *Terminalia sericea* savanna described above (Fig. 30), which occurs on the sandy soils in the higher rainfall lowveld near the escarpment. This vegetation type continues up to about 18 km from the coast and is often destroyed by a primitive type of cultivation and numerous orchards of *Anacardium occidentale* (cashew). Along drainage lines *Syzygium cordatum* is common.

About 18 km before the east coast of Africa is reached at Vila Luiza, the transect enters the coastal belt with a tropical rainy climate (Aw with annual rainfall 900 — 1 100 mm) and with deep sandy soils interrupted by wide, marshy and clayey flood plains and lagoons. On the clayey and marshy soils extensive grasslands and swamp vegetation types occur. The

FIG. 29.—**Acacia nigrescens-Sclerocarya caffra** Savanna on heavy basaltic soil west of the Lebombo Mountains.

FIG. 30.—**Terminalia sericea** Woodland on sandy soil in eastern Lowveld.

grasses are up to 1,5 m tall and cover up to 100 per cent. Important species are *Setaria holstii, Ischaemum brachyatherum, Chloris gayana, Panicum maximum, P. deustum* and others. *Acacia xanthophloea* and *Hyphaene crinita* are common in these grasslands. In inundated areas *Imperata cylindrica, Cyperus papyrus, Phragmites* spp., *Juncus* spp., *Typha* sp. and *Eichhornia crassipes* are found. On the sandy soils the natural vegetation is a dense forest, but in the area where the transect runs, this forest has largely been destroyed and has also been replaced by *Anacardium occidentale* orchards and primitively-cultivated lands. Patches of the dense forest with trees up to 15 m high still occur, and include the following species: *Afzelia quanzensis, Brachylaena discolor, Sclerocarya caffra, Trichilia emetica, Albizia adiantifolia, Garcinia livingstonii,* and others (Gomes Pedro & Grandvaux Barbosa, 1955; Tinley, 1971). Closer to the coast a dune forest, which is on the outermost dunes and is therefore pruned by the wind to a coastal scrub (Figs. 31 and 32) is found. The dune forest includes *Dialium schlechteri, Scolopia zeyheri, Brachylaena discolor* and others. The coastal scrub includes *Mimusops caffra, Brachylaena discolor, Diospyros rotundifolia, Vepris lanceolata, Euclea natalensis* and *Acacia robusta.* On the beach the pioneer sand binders are *Scaevola thunbergii, Ipomoea pes-caprae, Canavalia maritima, Sophora tomentosa* and *Tephrosia canescens.*

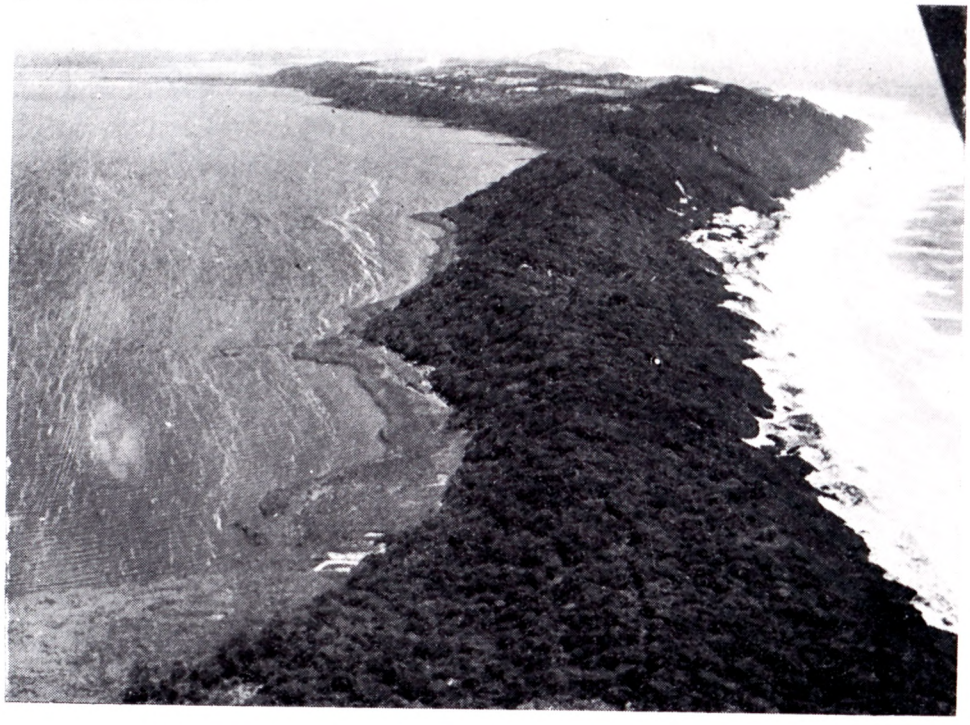

FIG. 31.—Dense coastal forest on dune with Indian Ocean on right and fresh-water lagoon on left (Photo: E. J. Moll).

FIG. 32.—Wind-pruned dune scrub near the coast (Photo: E. J. Moll).

DISCUSSION

Main vegetation discontinuities

Eleven main discontinuities in the structure and floristic composition of the vegetation along the transect are strongly related to a climatic gradient across the continent.

1. The true Namib desert occurs between the west coast and the escarpment in the winter rainfall desert climate with a sporadic annual rainfall of less than 100 mm. It is distinguished by a very low vegetation cover of less than one per cent, consisting mainly of succulents and other xerophytes and is entirely unsuitable for grazing of any form (Rattray, 1960). In the cool desert with frequent fog along the west coast, plants occur more commonly than in the hot inland desert where virtually no vegetation is encountered over extensive areas.

2. In the cool, summer rainfall, desert climate of the Vornamib on the western escarpment, the rainfall is below 100 mm and in the cool desert climate of the westernmost interior plateau, it is between 100 mm and 300 mm. Here the vegetation cover increases to between 5 and 25 per cent with local patches of grass on deep sand covering up to 40 per cent. In the Vornamib low open grasslands are found on sandy soils while dwarf shrubs are dominant on litholitic soils. Trees occur only occasionally in this area. On the loamy and litholitic soils further east where the annual rainfall increases to over 100 mm and becomes less sporadic, dwarf shrubs and shrubs become dominant with short grasses more abundant in sandy patches. Trees occasionally cover up to 2 per cent except for the shale ridges near Seeheim where trees and shrubs cover up to 15 per cent. Further east on the deep Kalahari sands, where the rainfall is still below 200 mm, the vegeta ion is largely a very open tree or shrub savanna with a tall open grass understorey. At the 200 mm isohyet trees gradually become more important and the species composition changes even though the Kalahari sand continues for another 100 km.

3. From about 50 km west of Hotazel to Kuruman, where the climate changes from a desert type to a cold dry steppe and the rainfall is between 300 and 400 mm, the total cover of the vegetation increases and is usually between 25 and 40 per cent. A tall tree savanna with shrubs and grasses occurs on sandy areas west of Hotazel. The tree cover varies between 5 and 25 per cent and the grasses are mainly "white" *Stipagrostis* spp. of the Karoo-Namib Region. The soils between Hotazel and Kuruman are mainly litholitic loamy sands and carry an open to fairly dense shrub savanna with "purple" grasses of the Sudano-Zambezian Region.

4. On the Ghaap Plateau, a vast plain of calcrete and dolomite extending from Kuruman over a distance of 170 km eastward, the total cover of the vegetation has increased to between 60 and 80 per cent. The rainfall is here between 400 and 500 mm and the climate belongs to the cold dry steppe type. A dense shrub savanna occurs on exposed calcrete or dolomite. One metre tall grasslands occur where the rocks are overlain by a thin layer of Kalahari sand.

5. From about 25 km east of Vryburg to Derby, a distance of 250 km, the vegetation is mainly dense grassland, changing in species composition from xerophytic grasses to sour mesophytic grasses as the rainfall increases from 500 mm in the west to 700 mm in the east. Near Lichtenburg at the 600 mm isohyet, the climate changes from the cold dry steppe to the hot dry steppe type. Stands of savanna occasionally occur on the flat to undulating plains in the west and become more regular on low ridges and hillsides towards the east. Trees are absent, however, over most of the area, probably as a result of severe frost. Regular burning is also con idered to be an important factor which restricts the occurrence of trees, particularly in the eastern higher rainfall area. Local variation in floristic composition is related to topographical position on the gently undulating plains while pedological features as well as exposure, slope and aspect are important factors in the more broken terrain.

6. Savannas and woodlands, with a grass cover varying from sour to a mixture of sour and sweet, occupy most of the lower eastern interior plateau from Derby to 25 km east of Groblersdal. The rainfall is between 600 and 700 mm over most of this area and the climate is of the hot and dry steppe type. In these respects it corresponds to the grasslands of the upper central interior plateau, from Vryburg to Derby, but frost is markedly less severe. Soil differences again account for variation in floristic composition in the gently undulating areas, and pedological features, exposure, slope, aspect and altitude for the variation in mountainous terrain.

7. In the temperate rainy climate of the high sandy plateau bordering on the eastern escarpment zone, dense sour grasslands occur, which are related to those of the central interior plateau and to local patches of grassland on top of the Magaliesberg. The rainfall is between 700 and 800 mm over most of this area and severe frosts occur regularly. Occasional stands of savanna vegetation are found on rocky outcrops and occur more widely on rocky hillsides in the strongly rolling to mountainous landscape towards Lydenburg. These savannas are also related to those found in the areas with higher rainfall of the upper central, interior plateau and on the Magaliesberg.

8. A local, but floristically very distinct type of savanna occurs in the Steelpoort Valley which, owing to its lower altitude, has a hot, probably frost-free climate and interrupts the previously-mentioned plateau bordering on the escarpment zone. The rainfall in this valley is between 500 and 600 mm.

9. Dense, mesophytic grasslands with an Austro-afro-alpine element and Afro-montane forests occur on the eastern escarpment which rises to 2350 m altitude. Rainfall on the escarpment is above 1750 mm and severe frost is a regularly-occurring phenomenon.

10. The area between the escarpment and the east coast is virtually frost-free and from Sabie as far as 18 km from the east coast a hot and dry steppe climate prevails with an annual rainfall varying between 600 and 900 mm. This area carries a savanna and woodland vegetation, sometimes up to 10 m in height. The savannas of the higher rainfall areas with sandy soils, near the escarpment and east of the Lebombo Mountains, are distinct in their floristic composition. In the central lower rainfall areas, floristically distinct types of savanna occur on different soils such as sandy granitic soils, clayey soils of depressions, termite mounds and basalt and litholitic soils of the Lebombo Mountains.

11. The sandy coastal belt, which has a tropical rainy climate with an annual rainfall between 900 and 1100 mm, is characterized by a number of distinct vegetation types including marsh and swamp communities, coastal dune forests and pioneer sand binding communities on the beach.

Thus, rainfall, the occurrence and severity of frost and possibly fire appear to be the most important differences related to the general physiognomic and structural variation of the vegetation along the transect from west to east across southern Africa. The vegetation becomes denser as the rainfall increases and along the same gradient a sequence of structural changes, related to growth form and cover, is apparent. These range from desert vegetation of succulents and other xerophytic growth forms to dwarf shrub steppes or xerophytic grass steppes, shrublands or xerophytic grasslands, shrub savannas with an understorey of xerophytic grasses, tree savannas with an understorey of xerophytic grasses, mesophytic grasslands or tree savannas and forests.

In the lowest rainfall areas vegetation is necessarily absent or very open and vegetation structure is not a prominent feature of the landscape. In the lower rainfall areas soil depth determines whether the vegetation is grassy or predominantly woody. The woody vegetation occurs on the shallower soils and is either dwarf shrub steppe, shrubland, shrub savanna or tree savanna depending on the rainfall. Walter (1962), in discussing the antagonistic relationships between grasses and woody plants, ascribes the occurrence of woody plants on shallow soils in the lower rainfall areas to their coarse and extensive root systems being better adapted than the root systems of grasses to reach the non-uniformly distributed water supplies in shallow and stoney soils. On deeper soils in the more arid regions, the finely branched and intensive root systems of grasses deplenish available water, which then does not penetrate below the grass roots and is thus not available for woody plants during the dry season. In the higher rainfall areas, some water is left by the grasses and this enables woody plants to survive the dry season, their heights and total cover increasing as rainfall increases.

In the higher rainfall areas, however, whether the vegetation is grassland or savanna seems to depend also on the absence or regular occurrence of severe frosts and fire. Presence of the latter two factors favours grasslands. Soil depth appears to be an overriding factor as rocky soils carry a tree growth

even in areas where severe frosts and fire regularly occur. Acocks (1953) suggests that the rocky areas provide some protection against fire. It may be speculated that microclimatic conditions between rocks provide some protection for young stems against frost and that moisture conditions favourable to the extensive root systems of woody plants, together with protection against fire, enhance the growth of woody plants to bigger and more frost resistant individuals. Protection against fire may be particularly important for the growth of woody plants in areas with severe frost, since fire damage is probably more severe if preceded by frost damage.

Floristic variation within the main structural types described above, is largely related to rainfall, severity of frost, soil conditions, exposure, slope and aspect.

Carrying capacity for animal husbandry

According to data provided by Rattray (1960) the main vegetation classes distinguished above coincide largely with major differences in carrying capacity of the vegetation. Rattray (1960) indicates that the true Namib is entirely unsuitable for grazing in any form. The remainder of the area under the desert climatic régime is suitable for sheep and cattle farming and has a carrying capacity of 2, 5–6 hectares per sheep or 26–35 hectares per beast. The area within the BSKw′ climate, comprising the transition from the Kalahari to the grassland vegetation of the Ghaap plateau and part of the grasslands of the upper central interior plateau, have a carrying capacity of 8 to 13 hectares per beast. Within the hotter steppe climates (BShw) as far as Groblersdal, the carrying capacity is between 2,5 and 5 hectares per beast on sour grass vegetation and between 5 and 7,5 hectares per beast on mixed-sweet and sour grass vegetation. Between Groblersdal and Sabie, with the exception of the Steelpoort Valley, the carrying capacity on the sour grasslands and savannas of the eastern escarpment in the Cw climatic régime amounts to 1–3,5 hectares per beast, and the vegetation is also suitable for sheep farming. From Sabie eastwards over the zone with the hot and dry steppe climate (BShw) the carrying capacity is between 2,5 and 5 hectares per beast. For the coastal belt with the tropical rainy climate (Aw) Rattray (1960) gives no carrying capacity figures.

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UITTREKSEL

Veranderings in die oorheersende plantegroei-fisionomie, prominente species en fisiografie, langs 'n roete wat 'n 1800 *km transek deur suidelike Afrika naby die Steenbokskeerkring volg, word beskryf. Elf hoof diskontinuïteite in die struktuur en floristiese samestelling van die plantegroei in die transek, hou verband met 'n klimaatgradiënt oor die Kontinent. Floristiese variasie binne die hoof strukturele tipes hou hoofsaaklik verband met reënval, strafheid van ryp, grondeienskappe, blootstelling, helling en aspek. Die hoof plantegroeiklasse wat onderskei is, val saam met hoof drakragverskille van die plantegroei.*

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