A GEOGRAPHICAL STUDY OF THE CAPE MIDLANDS AND EASTERN KARROO AREA WITH REFERENCE TO THE PHYSIOGRAPHY AND ELEMENTS OF LAND USE

by

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PREFACE

This study is the result of research conducted over a period of two and a half years. During this time I was a member of the Institute of Social and Economic Research at Rhodes University. Different research fellows in various disciplines have been engaged upon surveys of the Cape Midlands and Eastern Great Karroo area; due to this, and to eliminate any possible overlap in the material studied, this study is limited in scope.

Grateful thanks are tendered to many organisations and persons, both in the research area and elsewhere:

Firstly, I owe a great deal to Professor D. Hobart Houghton, Director of the Institute of Social and Economic Research, for valuable comment and moral support.

Secondly, the various government departments; in particular I am indebted to the Department of Planning for office accommodation, cartographic services and other assistance. I very much appreciate the assistance given to me by the Director and staff of Trignometrical Survey, Pretoria.

Thirdly, I should particularly like to thank my colleagues at the Institute of Social and Economic Research and in the Department of Geography, Rhodes University, with whom I have discussed parts of the study.

Fourthly, I am also most grateful to Mrs L. C. Vroom and her staff who typed the manuscript; to Mr S. T. Fullarton, for burning the midnight oil, and printing the colour maps; Mrs A. Maritz who assisted me with the statistical calculations; and Mrs L. S. Henderson who was willing to proof read some of the chapters.

Lastly, my thanks are due to Mr W. J. F. du Toit, from the Rand Afrikaans University, who guided me with the chapter on Land Use. My supervisor, Professor V. S. Forbes, I owe more than can be expressed in a formal acknowledgement.

J. J. Badenhorst

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INTRODUCTION

Geography is the discipline that seeks to describe and interpret the interrelations of phenomena on the earth's surface and their areal differentiation, to give comprehension of the earth as the world of man. Areal variation as it appears over the earth, has always been a stimulus to the imagination of man, and particularly to that of geographers. In the case of geography as opposed to that of other sciences, the emphasis has been on the understanding of this areal variation from the earliest times. In order to come to a better understanding of this areal variation, the geographer makes use of the regional method. "The regional concept* is a device to comprehend likenesses and differences on the earth's surface. A region (an intellectual concept) has some kind of internal homogeneity which distinguishes it from surrounding areas. Its distinct character may be perceived in the uniformity of its landscape features or in its modes of life, or it may be inferred from the way all parts work together in a functional system. A region is an areal generalisation. It is always defined in terms of specific criteria."[1]

Regions have no fixed size. They range from areas no larger than a small river valley to areas as big as South Africa or South-East Asia. Smaller regions can be combined to form larger ones, or larger ones can be divided into smaller units. Of necessity the degree of generalization will change, corresponding to the scale or extent of the investigation. "Many disputes about the validity of observed regularities could be eliminated if opponents took careful note of the scale on which the investigation was conducted. For the same reason it appears fruitless to argue the merits of either macroscopic or microscopic studies. The nature of the problem should determine the scale of the inquiry, and the latter should in turn guide the degree of magnitude of the generalisation".[2]

"The regional movement in South Africa, as has generally happened elsewhere, has originated as a popular movement most clearly represented by the 15 regional development or public bodies associations which have arisen during the past 25 years ... and represents the clearest manifestation of the growth of regional consciousness in South Africa. Each possesses a strong community of interest and, though there is a strong geographic basis for this, the areas of these regional groups do not everywhere coincide with the broad geographic regions that we recognize in this country. In addition, the regional movement, as represented by these associations, partakes of the nature of sectionalism and cannot be defined as true regionalism. The reasons for this and for some of the weaknesses of these bodies in regard to regional planning are important, because the tendency is to use these associations as the local communal foundations for regional planning and development."[3] Although these Development Associations can create

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* Du Toit, W. J. F., The Physiography and Aspects of Land Use in the Central Karroo Area. A Geographic Study of Regions of Minimal Deviation, Unpublished M. Sc. Thesis, Rand Afrikaans University 1968, pp 1-11. (In this work the author gives an exposition of the development of the regional concept in Geography)

1. Broek, J. O. M., Geography : Its Scope and Spirit, Charles E. Merrill Books Inc., Columbus, Ohio, 1967, p. 73
2. Ibid., p. 75
3. Fair, T. J. D., "Sections and Regions in South Africa in relation to Planning", South African Geographical Journal, Vol. 33, 1951, p. 5

difficulties, particularly in the delimitation of planning and development regions, they occupy a particular position in the regional movement in South Africa, and it would be unwise to ignore the importance of their spontaneous development. "They represent, without doubt, a transitional stage between lack of planning and true regional planning."[4]

According to Map 1 it is clear that the research area overlaps part of the Great Karroo and the Eastern Province. The question may arise as to why this particular part of the Cape Province, that is heterogeneous in nature in more than one respect, was chosen as a research area. During July 1966, Rhodes University was approached by the Karroo Development Association in connection with a socio-economic survey of the magisterial districts of Aberdeen, Graaff-Reinet, Jansenville and Murraysburg. Similar requests were soon after received from the Cape Midlands Development Association and individual responsible persons. The original request of the Karroo Development Association thus expanded from 4 to 21 magisterial districts in the course of a few months.

Because of the arbitrary manner in which the research area is demarcated, it is doubtful whether it can qualify as a region on its own. However, the possibility exists that there are regions within the research area. In order to prevent confusion the 21 magisterial districts will be referred to as the research area in the rest of this study.

This study is primarily concerned with the physiography,* elements of land use, and a statistical cartographic analysis of some of these elements. In the description of the chosen elements, particularly with regard to stock-farming as an important activity in the research area, attention has briefly been given to the historical development, since geography has an historical dimension. "Even those geographers who concentrate on the present recognize the genetic aspect. How far and in which manner one shall trace the present back into the past depends on the nature of the problem as well as on the interest of the investigator."[5] For the sake of a better ordering of the facts, the subject has been approached in the conventional geographic manner in successive chapters, Relief, Geology, Soil, Climate, etc. In practice, the relationship between geographic factors and land use is so close that it is usually very difficult to separate the one from the other. When there is any reference to a specific relationship in any chapter, it must be borne in mind that one must always take the other geographic factors into account. In this study the stress falls on an evaluation of the present land use. Even if there is no recommendation regarding the way in which the land should be used, this survey can still be used as the basis for future planning.

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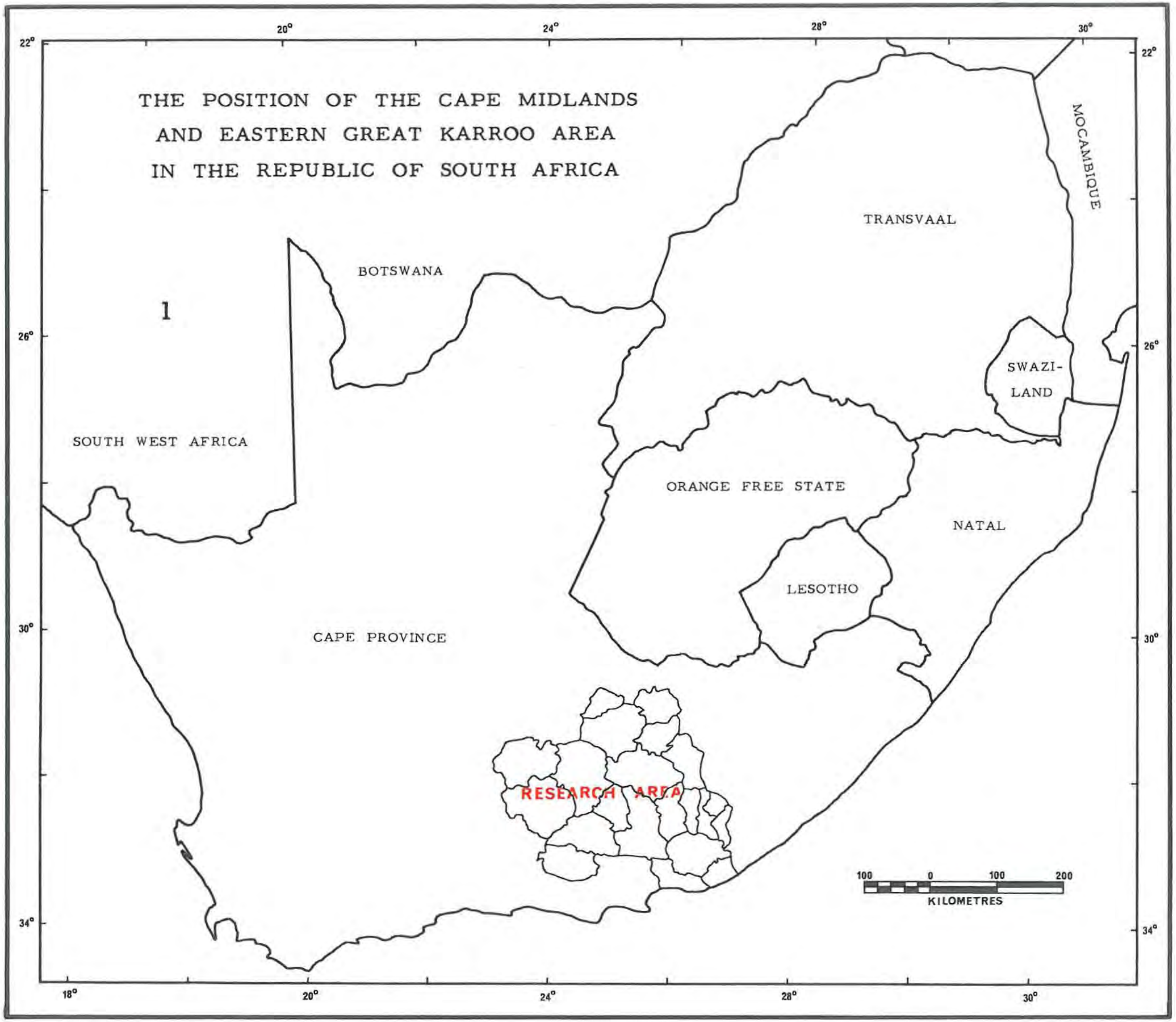
* Monkhouse, F. J.; A Dictionary of Geography, 1965 (Original definition of physiography - a description of nature, or of natural features in their causal relationship).

4. Ibid., p. 12
5. Broek, J. O. M., op. cit., p. 30



THE POSITION OF THE CAPE MIDLANDS
AND EASTERN GREAT KARROO AREA
IN THE REPUBLIC OF SOUTH AFRICA
1
BOTSWANA
TRANSVAAL
MOCAMBIQUE
SWAZI-
LAND
SOUTH WEST AFRICA
ORANGE FREE STATE
NATAL
LESOTHO
CAPE PROVINCE
RESEARCH AREA
100 0 100 200
KILOMETRES
20°
24°
28°
30°
22°
26°
30°
34°
18°

CHAPTER 1

ELEMENTS OF PHYSIOGRAPHY AND THEIR RELATIONSHIP TO LAND USE

A. SITUATION AND EXTENT

The research area comprises 72, 462 square kilometres. It is situated within the southern interior of the Republic of South Africa, between south latitudes 30° 56' and 33° 47' and east longitudes 23° 5' and 27° 7'. The maximum east-west width is 341 kilometres, while the maximum length, northwards from the coast, is 312 kilometres. The fairly straight coastline which runs roughly east-west, is slightly longer than 64 kilometres.

The research area comprises 10. 11% of the total Cape Province surface area, and its circumference follows the boundaries of 21 magisterial districts. Table 1 records the various magisterial districts and their individual surface areas, expressed as a percentage of the total research area. It will be seen from this table that there is considerable variation in size among them, Aberdeen being the largest (9. 47%) and Stockenström (1. 12%), the smallest.

	STOCKENSTRÖM	VICTORIA EAST	FORT BEAUFORT	BATHURST	NOUPOORT	ADELAIDE	MARAISBURG	ALEXANDRIA	PEARSTON	BEDFORD	STEYNSBURG	TARKASTAD	STEYTLERVILLE	ALBANY	JANSENVILLE	MURRAYSBURG	SOMERSET EAST	MIDDELBURG	CRADOCK	GRAAFF-REINET	ABERDEEN	RESEARCH AREA
Area in sq kilometres	813	956	1282	1471	1481	1544	2380	2440	2577	2608	2722	3196	3623	4406	4584	5421	5625	5742	5939	6786	6866	72462
%	1.12	1.32	1.77	2.03	2.04	2.13	3.28	3.37	3.56	3.60	3.76	4.41	5.00	6.08	6.33	7.48	7.76	7.92	8.20	9.36	9.47	100

TABLE 1 : SURFACE-AREA COMPARISON OF THE 21 MAGISTERIAL DISTRICTS

To the north and south the boundaries of the research area approximately follow the natural boundaries, namely the Great Escarpment in the north (Bamboesberg, Suurberg, Kikvors Mountains, Agter-Renosterberg and Sneeuberg). To the south, the boundary follows the coastline for more than 64 kilometres, moving westwards into the Suurberg, Klein Winterberge and Baviaanskloof Mountains.

The research area is bisected, roughly east-west, by a natural boundary, namely the Second Escarpment which will be discussed in

RELIEF AND RIVERS

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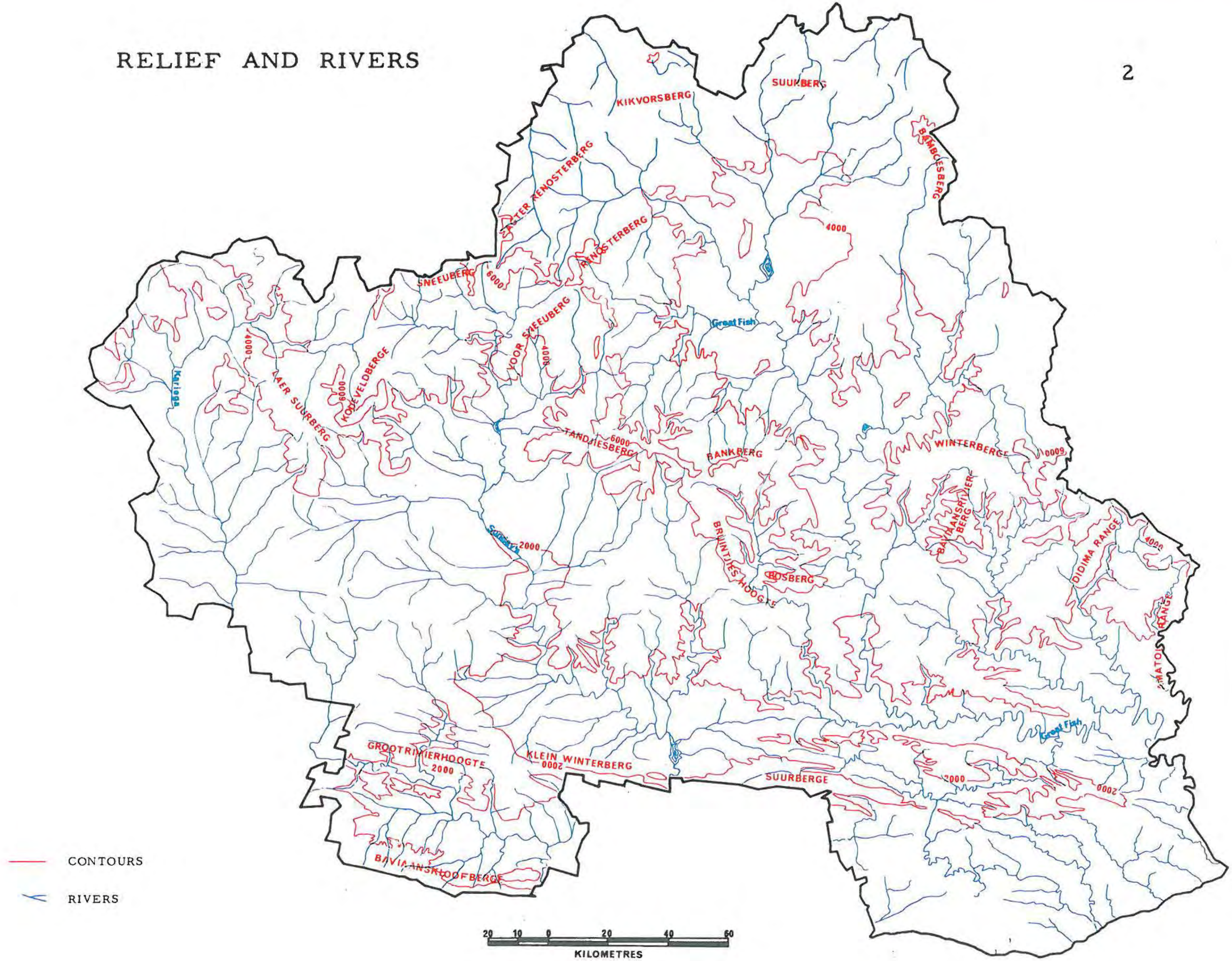
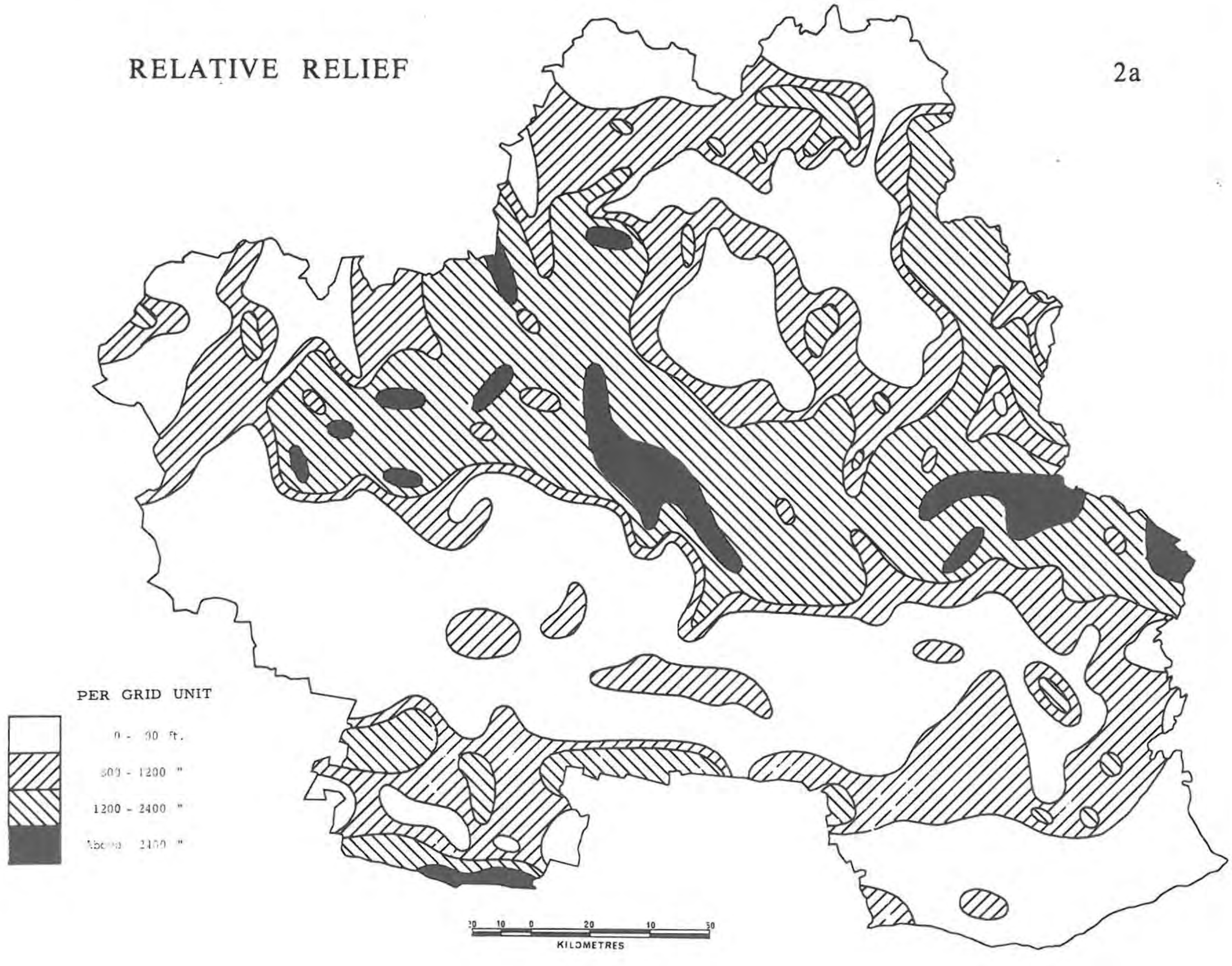


RELATIVE RELIEF

2a



more detail later. The relative relief* displays the following interesting characteristics namely, 5% mountains, 23% very mountainous or broken terrain, 10% hilly or broken terrain and 54% rolling or flat.

B. RELIEF

The research area constitutes part of the south-eastern sector of the Republic and embraces the following relief regions:

1. The Great Escarpment in the north.
2. A composite plateau immediately to the south of the Great Escarpment, consisting of:
   (a) the Second Escarpment
   (b) the Midlands
3. The Cape or Southern Fold Belt
4. The Coastal Plateau area between 300 and 600 metres
5. The Coastal Belt, generally rising to between 150 and 300 metres
6. The Great Karroo

1. The Great Escarpment

Two primary sub-divisions are particularly noticeable in the classification of the physiographic regions of South Africa, viz. the plateau and the adjacent area. The latter, which makes up the greater part of the research area is not merely a coastal belt, but consists mainly of plateau slopes that originated as a result of headward erosion of the Kariega, Sundays and Fish Rivers and their respective tributaries cutting continuously into the edge of the plateau and forcing its recession.[1] L. C. King rightly points out that: "throughout its length the Great Escarpment shows no association with faulting and can be attributed wholly to erosion".[2]

The South African escarpment at the southern edge of the plateau

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* The relative relief is calculated according to a scale in which the difference between the highest and lowest points within a square of 5 minutes of arc (about 8 kilometres) is as follows: mountains 610 metres and higher; very mountainous or very broken terrain 305-610 metres; hilly or broken terrain 152-305 metres; and rolling or flat 152 metres and lower.**

** These are the approximate metric equivalents of contours at 2000 ft., 1000 ft., and 500 ft.

1. Wellington, J. H. A., "A Physiographic Regional classification of South Africa", South African Geographical Journal, Vol. 28, 1946, p. 66

2. King, L. C., South African Scenery, Oliver and Boyd, London 1951, p. 264

forms the northern boundary of the research area[3] and be taken roughly as the watershed between the north-flowing tributaries of the Orange River and the southern coastal rivers, in particular the Kariega, Sundays and Fish Rivers.[4] The inland plateau region is vast and without any outstanding local relief features. The Orange River and its tributaries have dissected the area and over the greater part the soil is thin, except in the river valleys where alluvial soil is found.

From the Sneeuberg the plateau runs east to the Kompasberg, whence it curves to the north and then east along the Agter-Renosterberg, Kikvorsberge, Suurberg and Bamboesberge. Between the Bamboesberge and Stormberge the escarpment is not as prominent or outstanding as it is to the east. This difference is of importance and is closely related to the nature of the area lying to the south. The escarpment is nonetheless clearly defined and prominent because it is formed by the headward erosion of the Sundays and Fish Rivers along practically the whole of the northern boundary. Certain parts of the escarpment are vague and without definite edge. One of the most interesting breaks in the continuity of the plateau edge lies between the Nieuweveld and Sneeuberg. This 100 kilometre-wide 'gap' rises with almost a gentle slope from the Great Karroo up to the High Veld and attains its greatest height 50 kilometres to the north of the Nieuweveld-Sneeuberg opening. This 'gap' probably came into existence as a result of the absence of the dolerite layer that is so strongly developed in both the Nieuweveld and Sneeuberge. Fragments of this sheet are visible on the tops of a few isolated peaks in this gap, and indicate that the layer was originally very weakly developed and could not offer any strong resistance to the headwater erosion of the Salt and Kariega Rivers.[5]

A great number of streams have their origin in the plateau, but only a few relatively large rivers rise here. To the east of the Kamdeboo and Lower Suurberg the Kariega runs south; the Bloukrans River rises in the Sneeuberg and joins the Sundays River to the south; the most important tributaries of the Great Fish River are the Great Brak River that drains the region to the south of the Suurberg; the Vlekpoort River that rises in the Bamboesberg, joins the Tarka River, and the latter joins the Great Fish River to the south of Cradock.[6]

2. The Composite Plateau Area

The intermediary highlands of the Eastern Province are classed as a composite plateau area by Els, and is divided in two, viz. the Second Escarpment and the Midlands.

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3. Rennie, J. V. L., "The Eastern Cape as a Geographical Region", South African Geographical Journal, Vol. 27, 1945, p. 1

4. Wellington, J. H., "Some Physical Factors Affecting the Economic Development of the Eastern Cape Province and Adjoining Areas", South African Geographical Journal, Vol. 11, Dec., 1928, p. 23

5. Wellington, J. H., 1946, op. cit., p. 66

6. Els, W. C., Die Ewolusie van Grondgebruik in die Groot Visriviervallei, Ongepubliseerde D. Litt, et Phil Proefskrif, UNISA, 1965, p. 18

(a) The Second Escarpment

A prominent feature of the composite plateau to the south of the Great Escarpment and one that is restricted to the Eastern Province, is the strongly developed mountain range, also known as the Second Escarpment or Tandjiesberg-Winterberg orographic line.[7] This escarpment is not only lower-lying than the Great Escarpment, but is also an unbroken hilly and mountainous belt, 50 to 80 kilometres wide, with about half of it lying between 1,500 and 1,800 metres above sea level. "The region is so mountainous that agriculture can hardly be carried out, and the region is then exploited mainly as summer grazing from the surrounding lower-lying regions."[8]

It is probable that the Great Escarpment originally ran along the presently well-defined Second Escarpment. This strongly developed orographic line breaks away from the Great Escarpment at approximately Kompasberg (2,460 metres) and can be clearly seen in the Tandjiesberg, Bankberg, Winterberg, Elandsberg above Seymour and the northern portion of the Amatola Range consecutively, finally ending in the Dohne Peak, situated at the eastern extremity of the Kologha range above Stutterheim.[9] To the east of Stutterheim the prominent features of this orographic line fade, as one would expect in a coastal region with a reasonably high rainfall. Structurally, the Second Escarpment corresponds to the Great Escarpment, while its plateau-like character distinguishes it from the Cape Fold Belt in the south.

Geographically speaking, this range is of importance in that it is an important watershed and obstacle to traffic in respect of the Great Fish River basin, except to the south of Cradock where the Great Fish River cuts between Bankberg and the Baviaans River Mountains. On the southern slopes of theSecond Escarpment, there are various mountain projections; Coetzeeberg and Groot Bruintjieshoogte, Baviaans River Mountains, Klein Winterberg, the Didima range and the Amatola range, between which there are consecutive basins and catchment areas, and include the upper reaches of the Sundays, Little Fish, Koonap and Kat Rivers.

(b) The Midlands

"Enclosed between the two orographic features (Great Escarpment and Winterberg-Amatola watershed) lie the headwater basins of the Great Fish and Kei Rivers, forming a sub-region which may be regarded as distinct from the Eastern Uplands or as the extreme southern portion thereof. The name Cape Eastern Midlands has been given to this basin."[10] Of these two catchment areas, only the Upper Fish River catchment area is of importance to this survey. To the north, west and south the Midlands have a distinct orographic boundary, while it has no definite orographic separation from the intensely dissected drainage area of the Kei River

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7. Rennie, J. V. L., op. cit., p. 2

8. Els, W. C., op. cit., p. 19

9. Rennie, J. V. L., op. cit., p. 2

10. Wellington, J. H., 1946, op. cit., p. 79

to the east, except for an arbitrary boundary along the Kei-Bashee watershed to the east of the Cala and Tsomo Rivers.[11]

Structurally, this region has the same character as the inland plateau, but differs from it by virtue of its lower altitude, and tends to drop gradually in the direction of the Winterberg from the Great Escarpment. The basin drops from 1,200 metres near Middelburg to 900 metres near Cradock.[12]

This saucer-shaped basin has a geographic entity of its own, and differs from the adjacent parts. As in the case of the Kei River basin, the land drops in the Middelburg-Cradock districts from the edge of the plateau in a series of basins or plains that are separated from one another by spurs which are the remnants of the former plateau. The level surface is frequently interrupted by table-kopjes, as for example the well-known Teebus, situated just north of the Rosmead-Steynsburg railway line, and the majestic Table Mountain to the north-west of Cradock.

From Noupoort to the south the terrace-like landscape consists of various basins. First there is the great amphitheatre below the Agter-Renosterberg and Kikvorsberge, also known as the Ludlow basin; then follow the smaller Sherborne and Bonger basins that run into the Middelburg basin, the last mentioned runs into the Teebus valley where the Great Brak River and Great Fish River unite to form the so-called Cradock basin, although Cradock is in actual fact situated at its southern entrance.[13]

3. The Cape Fold Belt

The Cape Fold Belt consists of a series of parallel mountain ranges that run from the west, in an east- south-easterly direction. Only the eastern extremity of this fold belt is found in the southern part of the research area and extends as far as the lower reaches of the Great Fish River where it strikes the curved coastline at an acute angle. "In a belt which narrows from 100 to 70 kilometres in width in the vicinity of Grahamstown, it introduces features of distinctly Western Province aspect well into the Eastern Cape."[14]

The coastal range ends in the Kareedouw Mountains at Cape St. Francis. To the north of the coastal range is the middle range, of which only Baviaanskloofberge fall within the research area where they form the southern boundary of the Steytlerville magisterial district. To the east this range runs into the Kouga and Great Winterhoek Mountains, about 30 kilometres from the present coast-line where they were originally eroded during a period of marine-transgression during the Cretaceous and Tertiary periods. The northern ranges represented by the Grootrivierhoogtes, the Klein Winterberg, Klein Winterhoek Mountains and the Southern Suurberg, are cut by the Sundays and Bushmans Rivers. To the east the prominence of the northern

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11. Rennie, J. V. L., op. cit., p. 5
12. Ibid., p. 5
13. Wellington, J. H., 1928, op. cit., p. 27
14. Rennie, J. V. L., op. cit., p. 2

range fades after being cut across by the Great Fish River; but the folding can be traced to the coast, where it appears in exposed sections.[15]

This Fold belt is not only of topographical importance, but it also forms an important climatological boundary. As the southern boundary of the Great Karroo, this belt contributes greatly to the arid conditions that are so noticeably part of the Karroo because it is a climatic barrier. Within this Fold belt there is habitable country with sufficient water limited between east and west for a considerable distance to a narrow transversely trenched and partly forested coastal shelf.[16] The small area with a high rainfall (500-750 mm.) along the southern slopes of the Suurberg forms a marked contrast to the area of lower rainfall to the south and the area of still lower rainfall to the north of the range.[17]

The arrangement of mountain ridges and valleys is due here not to the alternation of anticline and syncline, but to the erosive action of the streams of the area breaching the large regional anticlines. In this way the orographic arrangement around Grahamstown consists of two main ranges; Signal Hill range in the south and Botha's Hill range to the north, with Grahamstown lying in a broad valley between them.[18]

4. The Coastal Plateau

From a height of 60 to 90 metres at the coast, the landscape rises gradually northwards to a height of 600 metres. At this height there is no clear physical boundary, although the ascent to the Midlands area does have a step-like appearance at times. "This, however, is never a continuous feature, and is generally due to some local structural peculiarity, such as the occurrence of a block of Table Mountain sandstone."[19] Els defines the northern boundary as follows: "in the north it stretches southwards from the middle tributaries of the Little Fish, Koonap and Kat Rivers, in line with Bedford and parallel to the Winterberg orographic line".[20] To the west the coastal plateau extends into the Great Karroo. Here the extreme westerly continuation of the Winterberg-Amatola line, viz. the Groot Bruintjieshoogte, lying south of the Tandjiesberg, provides a convenient division between the two regions. It is not a linear boundary, but is definite enough to indicate the western boundary of the coastal plateau. To the east it reaches down to the coast where the Fish River flows into the sea.

In comparison with the adjacent highlands, the coastal plateau

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15. Wellington, J.H., 1928, op. cit., p. 24
16. Rennie, J.V.L., op. cit., p. 2
17. Wellington, J.H., 1928, op. cit., p. 24
18. Ibid., p. 25
19. Wellington, J.H., 1928, op. cit., p. 26
20. Els, W.C., op. cit., p. 25

as a whole appears as a reasonably level surface, with a gradual upward slope from the coast to the inland boundary. Closer investigation, however, reveals that the surface is anything but level, and exhibits a marked characteristic of a deeply trenched landscape, that has in many instances been dissected to a depth of 300 metres by the action of the rivers and their tributaries.

"There is no low-lying coastal plain and very little indeed in the way of alluvial flats, and human interests tend to focus within the several fairly smooth interfluve areas which are blocked off by the more or less wooded major valley zones." [21]

By way of contrast with the upper and middle course, the winding lower course of the Great Fish River generally has a ravine-like appearance with steep cliffs that appear periodically. There is, however, a marked variation in the general cross-profile of the river valley and it has a reasonably broad and open appearance at times.[22]

5. The Coastal Belt

One of the characteristics of the coastal belt is that it rises sharply to a height of 60-90 metres and that there is no low-lying coastal plain. The shoreline is not homogeneous in nature and has a varying aspect of rocks and sand dunes. In the vicinity of Port Alfred the dunes are exceptionally high and anchored by scrub grass, as in the vicinity of East London and to the east of Port Elizabeth. Elsewhere sand dunes, however, do not usually reach a great height, and do not extend more than 200 or 300 metres inland. The coastline is exceptionally straight in this area.

One of the physical characteristics of the coast that has a determining influence on the economic development of the region, is the nature of the river mouths. Eastwards from the Kowie River, up to the Tugela River, all the rivers are tidal and one would expect these tidal mouths to be ideal for the development of harbours. These tidal mouths are almost all obstructed by sandbanks, and are seemingly dependent on two related factors: the ability of the river to remove the beach material piled up by the action of the waves and the seasonal character of the river's regime. The latter is of some importance, since many of the largest rivers are generally scarcely able to keep open their channels to the sea during the dry season. With the advent of the rainy season, these small "winter streams" turn into rivers that often wash away the whole of the sandbank through which they have only been able to keep a narrow channel open during the winter season.[23]

6. The Great Karroo

The Great Karroo lies between the Cape Fold Belt and the Great Escarpment as far east as Kompasberg, to the east of which the

21. Rennie, J. V. L., op. cit., p. 4
22. Els, W. C., op. cit., p. 26
23. Wellington, J. H., 1928, op. cit., p. 27

Tandjiesberg and Groot Bruintjieshoogte continue the semi-circle arc of the Sneeuberg. Tandjiesberg and Groot Bruintjieshoogte form an orographic boundary between the Great Karroo and Midlands. There is no definite orographic division between the Great Karroo and the Coastal Plateau except for the high-lying area, known as the Groot Bruintjieshoogte that forms part of the watershed between the Sundays River and Great Fish River catchment areas.[24] To the east of the Gamka-Salt River watershed lies the "Eastern Karroo", that is an integral part of the research area. The rivers of the "Eastern Karroo", of which the Kariega and Sundays Rivers are the most important, flow southwards through the Southern Fold Belt.

"The Great Karroo is essentially a basin, or series of basins, formed by the headwaters of rivers that have cut back from the folded belt into the plateau surface."[25] The southern sector of the Eastern Karroo is characterised by the fairly monotonous Kendrew, Pearston and Jansenville basins with a height of approximately 600 metres above sea level. To the north the landscape rises gradually to the base of the Great Escarpment, where the surface changes to a basin with its exit in the vicinity of Graaff-Reinet.[26]

Summary

From a study of the topographical features of the research area, it is noticeable that there is no clearly defined central area of outstanding importance. On the contrary the region consists of a dissected landscape in which it is difficult to single out any catchment area or lowland that has more than purely local importance. As regards the main features, there is a clear reflection of the most important elements in the structure of South Africa as a whole.

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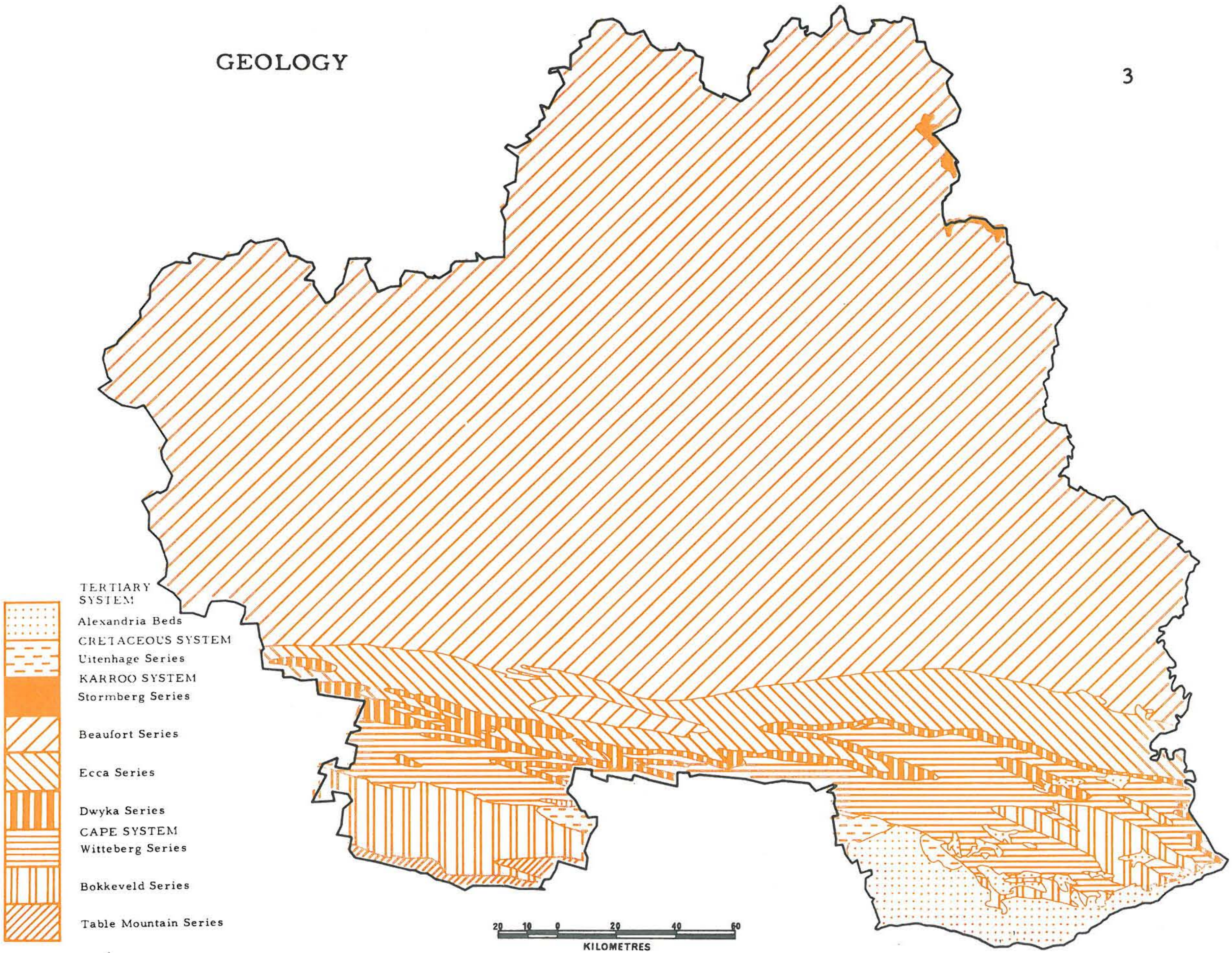
24. Wellington, J.H., 1946, op. cit., p. 82
25. Wellington, J.H., 1946, op. cit., p. 82
26. Rennie, J.V.L., op. cit., p. 5

GEOLOGY


TERTIARY SYSTEM
Alexandria Beds
CRETACEOUS SYSTEM
Uitenhage Series
KARROO SYSTEM
Stormberg Series
Beaufort Series
Ecca Series
Dwyka Series
CAPE SYSTEM
Witteberg Series
Bokkeveld Series
Table Mountain Series
20 10 0 20 40 60
KILOMETRES

C. GEOLOGY

Landscape, as we know it today, has been created by a continuous alteration between endogenetic forces on the one hand and exogenetic factors on the other. A discussion of the geological background of various rock formations, and especially of their incidence in the research area, is essential in order to gain a sound understanding of the present form and character of the landscape. Geological formation is important because, with rainfall, it exerts a controlling influence on underground water supplies. Moreover, when rocks are exposed to the atmosphere, the process of weathering liberates the elements necessary to soil formation.

The geological evolution of South Africa can be traced through five major periods, namely Archaean, Postarchaean-Prebushveld, Postbushveld-Prekarroo, Karroo and Postkarroo.[1] The fundamental complex was reduced, in the course of protracted geological ages, to a peneplain. This stratum or Archaean Basement was to form the foundation upon which were deposited all succeeding geological formations. Rock formation in the research area date back to three major ages: Postbushveld-Prekarroo, Karroo and Postkarroo.

Postbushveld-Prekarroo and Karroo Eras

1. Cape System

Shallow, extensive sedimentary deposits developed over the southern portion of what is now known as South Africa during the Postbushveld-Prekarroo era. Various rivers deposited sandy sediment in this basin, which gradually deepened. There is evidence of the first signs of an east-west geosyncline during the later Cape Period. In the course of time this geosyncline grew deeper and wider, and accumulated nearly 3000 metres of sediments.[2] Although this system shows signs of Prekarroo folding, the most important folding occurred in the Postkarroo era.

The Cape System is only found within the Cape Fold area. One characteristic of this system, compared with preceding ones, is that it contains a wide range of fossils. The formations of the Cape System are fairly easily distinguished; they consist of the following three conformable series:

(a) Table Mountain Series

(b) Bokkeveld Series

(c) Witteberg Series

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1. Mountain, E. D., Geology of South Africa, Books of Africa (Pty) Ltd., Cape Town, 1968, p. 33
2. Cook, H. B. S., "The Ancient Geography of South Africa", South African Geographical Journal, Vol. 32, 1950, p. 3

(a) Table Mountain Series

The oldest of the three series, named after Table Mountain (Cape Town), consists chiefly of homogenous sandstone and orthoquartzites formed under deltaic conditions. Its maximum depth is 1,500 metres. The sandstone structure grows rather coarser towards Natal, somewhat more feldspathic and browner in colour.[3] The sequence begins with reddish shale, followed by uniform orthoquartzite to a depth of approximately 600 metres. A tillite layer of about 30 metres follows, followed in turn by dark greenish shale and more sandstone.[4]

A surface ridge of Table Mountain sandstone characterises nearly all the important anticlines.[5] Because of its hardness and resistance to erosion, this series forms the mountainous areas. In the process of weathering, sandstone yields a sour, sandy, infertile soil which supports but meagre vegetation on the mountain slopes. Table Mountain sandstone serves as good building material, however.[6]

(b) Bokkeveld Series

This series consists of five major shale layers, each several hundred metres thick. They alternate with four intermediate sandstone and quartzite horizons, varying in thickness from 50 to 120 metres.[7]

This series ranges in age from Lower to Middle Devonian. An outstanding characteristic of the Bokkeveld Series is the quantity of Lower Devonian marine fossils to be found chiefly in the lowest shale layer and overlying sandstone.[8] Although the lower half of the Bokkeveld Series was deposited below sea level, the Upper Bokkeveld reveals a transition between deltaic and lake deposits. Mollusc fossils disappear and are replaced by plant fossils in the upper layers. This would indicate that the sea became shallower during the later Devonian period.[9]

In general, the main mountain ranges consist of Table Mountain Series and Witteberg Series formations, while Bokkeveld Series occurs in the valleys. In folded areas the quartzite layers appear as parallel cuestas while the shale layers form longitudinal valleys.[10] The shale yields brown, fertile soil after weathering, a fact discovered by the earliest settlers.

(c) Witteberg Series

It is likely that this series was deposited under deltaic conditions from the Middle Devonian until the Carboniferous period. It comprises chiefly quartzite. The lowest horizons are similar to Table Mountain

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3. Mountain, E.D., op. cit., p. 62
4. Ibid. p. 64
5. Du Toit, A.L., Geology of South Africa, Edinburgh, 1939, p. 237
6. Ibid. p. 248
7. Ibid. p. 250
8. Mountain, E.D., op. cit., p. 65
9. Du Toit, A.L. op. cit., p. 258
10. Mountain, E.D. op. cit., p. 65

sandstone, while the uppermost layers are represented by shale. The characteristic plant fossils of the Bokkeveld Series are also to be found in the lowest horizons of the Witteberg Series.[11] Although the soil yielded by these rocks is poor agriculturally, they form a good reservoir for underground water.

2. Karroo System

Except for its southern and south-eastern parts, the Karroo System is the main formation in the research area, and covers nearly 75% in surface area. This system was deposited during the Upper Carboniferous, Permian, Triassic and Lower Jurassic Ages.

The Karroo System occupies a unique position in South African geology. It consists of a vast deposit whose surface covers about half the Republic. It stretches over most of the central Cape Province north of the Cape Fold Belt, practically the entire Orange Free State, western Natal and large areas of the Transvaal.[12] The near-horizontal layers of the sedimentary rocks can be best observed in the southern part of the Karroo Basin where the Karroo system follows conformably on the Cape System. The total thickness here is approximately 7,500 metres[13] composed of thick layers of shale and sandstone resting on a basal layer of tillite and covered by a layer of basaltic lava. The individual layers can be sub-divided chronologically as follows:

(a) Dwyka Series

(b) Ecca Series

(c) Beaufort Series

(d) Stormberg Series[14]

(a) Dwyka Series

"Geologically this is one of the most important stages in the history of South Africa, because it marked the beginning of the Karroo System and, especially, of the Dwyka Series."[15] The outstanding characteristic of this period, apart from the widening geosyncline, is the development of a number of glaciated centres north of the geosyncline. Glacial debris was swept into the ever-sinking depression from the north and south. It would appear that most of the debris was carried from the south because tillite depth decreases northwards.

The Dwyka Series consists principally of shale and tillite. River sediment probably formed the shale which is light green or blue in colour and which occasionally contains narrow bands of sandstone. The presence

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11. Ibid. p. 65
12. Hamilton, G. N. G. and Cooke, H. B. S., Geology for South African Students, 1960, p. 257
13. Mountain, E. D., op. cit., p. 66
14. Hamilton, G. N. G. and Cooke, H. B. S., op. cit., p. 258
15. Mountain, E. D. op. cit., p. 122

of plant fossils would indicate that the geosyncline was filled with fresh water. The glacial deposits chiefly consist of tillite which is composed of blue or green glacial clay in which rock fragments of various sizes occur. These fragments originate from Prekarroo formations to the north. When an incomplete jointing, with a steep southwards dip occurs with vertical bedding planes with the same strike, the characteristic weathering known as Bushmans tombstones results.[16]

Upper Dwyka shale is only found here in the south (Map 3) and in South West Africa.[17] This second type of deposit with a thickness of 200 metres is apparently the result of a warmer climate, a surface depression and floods caused by melting glaciers in the north.

(b) Ecca Series

The Ecca Series follows the Dwyka Series conformably in the Cape Province. It reaches a depth of just on 3000 metres in the vicinity of the Cape Fold Mountains.[18] This series consists chiefly of mudstone, shale and sandstone, and was deposited during the Permian period. The Ecca Series is exposed as a broad outcrop of about 20 kilometres wide and comprises an area running east-west immediately to the north of the Dwyka outcrops.

The lowest Ecca consists of blue-grey shales and dark sandstone which thin out to the north.[19] These strata, deposited in the Karroo are folded with the Cape Fold Belt. In some places between Prince Alfred and Klipplaat the folding is so extensive as to appear vertical or even overfolded northwards. A depth of 3000 metres has been measured in the environs of Committees Drift along the Great Fish River.[20]

The formations comprising the Middle Ecca are mainly sandstones, carbonaceous shale and coal. It is doubtful whether this group occurs to any great extent in the Cape Midlands.[21]

Upper Ecca follows the coal deposits. It appears as a relatively thin layer of uniformly pale blue shale.[22] It attains a depth of about 240 metres in the south, and then thins out northwards to 150 metres. It can be distinguished from lower Ecca only by its high phosphate and lime content.[23]

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16. Mountain, E. D., Die Geologie van 'n gebied ten ooste van Grahamstad, Dept. van Mynwese, Geologiese Opname, Staatsdrukker, Pretoria, 1947, p. 13
17. Hamilton, G. N. G. and Cooke, H. B. S., op. cit. p. 259
18. Ibid, p. 260
19. Mountain, E. D., op. cit., 1968, p. 68
20. Du Toit, A. L., op. cit., p. 281
21. Hamilton, G. N. G. and Cooke, H. B. S., op. cit. p. 260
22. Ibid, p. 261
23. Wellington, J. H., 1928, op. cit., p. 27

(c) Beaufort Series

The Beaufort Series follows conformably on the Ecca and was deposited during the Upper Permian and Lower Triassic periods. Compared with other series, the Beaufort covers the major portion of the research areas as well as of the Republic as a whole.[24]

The Beaufort layers rest conformably on the Ecca layers, and their structure corresponds with that of the underlying Ecca. Its southern boundary is marked by folding although its dips are generally fairly low.[25] This series reaches its maximum depth in the south east.[26]

The geosyncline still existed in the south, but now the sedimentation was more rapid than the rate of subsidence. This resulted in periodic marsh conditions in which Karroo reptiles evolved.[27] The formations of certain areas are particularly rich in reptile fossils. Fossils of the Lower Beaufort Beds are abundant in the Graaff-Reinet area, and are found between Prince Albert and Beaufort West.[28]

The formations do not show much variety; they consist mostly of feldspathic sandstone and mudstone. The most notable difference between the Beaufort Series and the underlying Ecca is that the former includes red formations and contains a high shale-sandstone proportion.[29] This series may be divided lithologically into three stages, namely the Upper, Middle and Lower Beaufort.[30]

The Lower Beaufort Beds consist of yellowish feldspathic sandstone, alternating with blue, green, red and purple mudstone and shale which, in their maximum development in the South Karroo, attains a thickness of 2,100 to 2,400 metres.[31]

The Middle Beaufort Beds reach a thickness of 150 to 300 metres, of which the lower part consists of bright red, purple and green shale, and the upper layers of yellow sandstone interspersed with thin layers of mudstone and shale.[32] This series surrounds the Upper Beaufort and forms outcrops inter alia in the region of Middelburg (Cape).

The Upper Beaufort Beds or Burgersdorp bands consist of widespread yellow feldspathic sandstone which alternates with red, blue and green shale.[33] Once again, the maximum development is in the southwest (Queenstown), whence it gradually thins out northwards.

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24. Hamilton, G. N. G. and Cooke, H. B. S., op. cit., p. 262
25. Du Toit, A. L., op. cit., p. 290
26. Ibid., p. 291
27. Mountain, E. D., op. cit., p. 129
28. Du Toit, A. L., op. cit., p. 293
29. Mountain, E. D., op. cit., p 69
30. Hamilton, G. N. G. and Cooke, H. B. S. op. cit., p. 262
31. Ibid., p. 262
32. Hamilton, G. N. G. and Cooke, H. B. S., op. cit., p. 262
33. Ibid., p. 262

(d) Stormberg Series

These layers were deposited during the Upper Triassic and Lower Jurassic periods. The climate had warmed up; desert conditions began to penetrate southwards from the north; the deposits apparently occurred largely under these conditions. The Stormberg Series is divided into four stratigraphical stages, namely the Molteno Beds, the Red Beds, the Holkrans Beds and the Drakensberg Lava Beds. These layers consist principally of shale, sandstone and the overlying lava, which follows conformably on the Beaufort Series.

The Stormberg Series is represented in the research area by the Bamboesberge, which cover only a small area. (See Map 3).

3. Karroo Dolerite

After the deposition of the Holkrans sandstone and during the flow of the Drakensberg lavas, widespread intrusions of dolerite took place over a wide area into the Karroo Beds. These dolerites do not occur near the southern Cape Fold range. Their southern boundary follows a line drawn through Beaufort West, Aberdeen, Somerset East, Fort Beaufort and East London.[34]

Dolerite is also known as ironstone because of its hard nature, its rusty colour on weathering and the metallic sound it gives off when struck with a hammer.[35] It originated when basaltic magma intruded into the Karroo formations. It results in a slight measure of thermal and contact metamorphism. A hard, black rock, lidianite, formed as a result of this metamorphism.

Karroo dolerites exert a considerable influence on the movement and conservation of underground water.[36] This supply of water is particularly important in the Central Karroo where both man and beast obtains water by means of boreholes.

Postkarroo Era

The extent of Postkarroo formations is limited to a very small region in South Africa, namely, the marine beds along the coastline, and, to a smaller extent, continental types. Since marine deposits are relatively rich in fossils, these South African formations are sub-divided on the same basis as those of the Northern Hemisphere, at least insofar as those criteria are relevant here. South Africa had no period corresponding to the great ice age or Pleistocene period of the Northern Hemisphere. Consequently the Pleistocene and Quaternary formations cannot clearly be distinguished from the Tertiary: the following sub-division is made in South Africa: Cretaceous System.[37]

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34. Du Toit, A. L., op. cit., p. 360
35. Ibid., p. 360
36. Hamilton, G. N. G. and Cooke, H. B. S., op. cit., p. 268
37. Mountain, E. D., op. cit., p. 73

4. Cretaceous System

"Up to this stage, the Geography of the region bore very little resemblance to that of the present day South Africa, but in Cretaceous times the whole outline of the sub-continent was blocked out."[38] At the beginning of the Cretaceous System the coastline looked very different because at times certain parts were below the present sea level, while others were up to 360 metres higher. Apart from widespread deposits along the Mocambique Coast, similar deposits occur as east-west strips in the southern fold belt between the outcrops of resistant quartzite in the Cape System.[39]

The Cretaceous System ranges in age from 60 to 125 million years. This system can be sub-divided into various stages, of which the Uitenhage Series is one of the most important. Cretaceous formations are largely built up of shale, sandstone, limestone and conglomerate.

(a) Uitenhage Series

As its name indicates, this Series is found around Uitenhage, especially along the Sundays River Valley where three stages are distinguishable, namely Enon Conglomerate, Variegated Marls and Wood Beds, and Sundays River Beds.

The first and lowest stage is known as the Enon Conglomerate. The deposits are very tightly packed and the typical colours are yellowish-white and red. The boulders are from ½ to 1 metre across; they originate from the quartzites of the Cape System.[40] The conglomerates are well developed along the northern edge of the basin, except in places where shifting has taken place, as in the region of Sandflats. When all factors are taken into account, it would appear that most of these sediments came from the north.[41]

The Variegated Marls and Wood Beds follow, consisting of soft, yellow sandstone and green clay interspersed with alluvial pebble beds. The Wood Beds are developed particularly along the northern banks of the Kariega River depression, reaching a depth of approximately 900 metres. These layers are rich in fossils, with plant fossils dominating.

Then follows the Sundays River Beds which consist of blueish clay and shales, together with sandy limestone and sandstone. Large quantities and varieties of marine fossils are to be found in the formations.[42]

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38. Hamilton, G. N. G. and Cooke, H. B. S., op. cit., p. 268
39. Mountain, E. D., op. cit., p. 73
40. Ibid., p. 74
41. Ibid., p. 74
42. Hamilton, G. N. G. and Cooke, H. B. S., op. cit., p. 269

5. Postcretaceous System

Postcretaceous deposits are sub-divided in Europe into the Tertiary and Quaternary Systems, each having its own sub-divisions. This classification has its limitations in South Africa, however,[43] and the two sub-divisions should rather be lumped together.[44] There are few fossils here, and correspondence to the European system of classification is uncertain. It is convenient, if not satisfying, to distinguish here between coastal and continental deposits.

There is one example of Tertiary formations of marine origin in the research area, namely the Alexandria Formation. This rests on a marine platform sloping seawards at about 1 degree. These beds consist of hard, white or cream-coloured limestone, with layers of pebbles and sand which represent ancient coastal deposits. The sandy crystalline limestone is locally known as Bathurst Limestone.[45] The formations are also rich in fossils, those nearest the coast representing extant species.[46]

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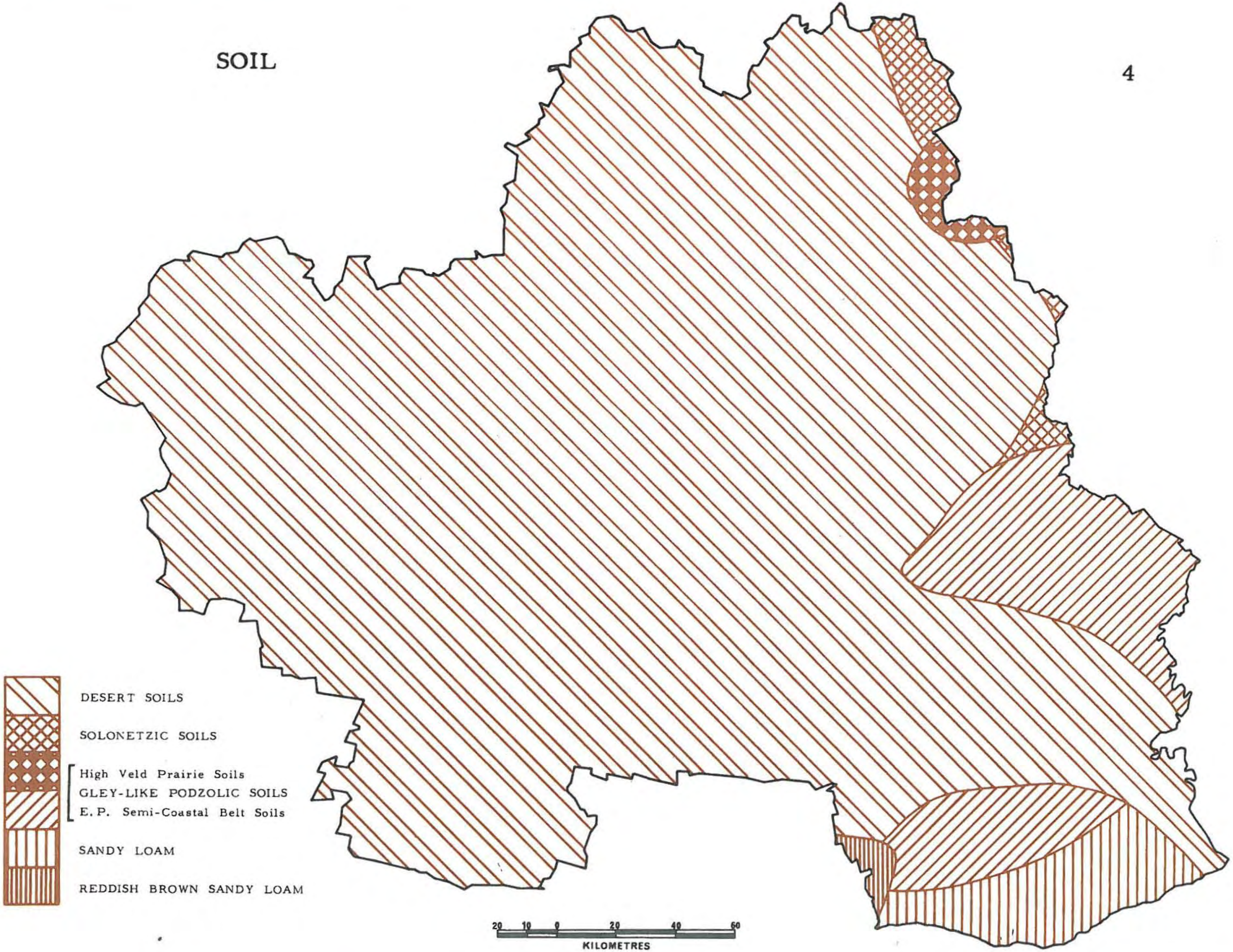
43. Mountain, E. D., op. cit., p. 77
44. Hamilton, G. N. G. and Cooke, H. B. S., op. cit., p. 277
45. Mountain, E. D., op. cit., p. 78
46. Ibid., p. 78

SOIL

4


DESERT SOILS
SOLONETZIC SOILS
High Veld Prairie Soils
GLEY-LIKE PODZOLIC SOILS
E. P. Semi-Coastal Belt Soils
SANDY LOAM
REDDISH BROWN SANDY LOAM
20 10 0 20 40 60
KILOMETRES

D. SOIL

Bushnell (1944) defined soil as follows: "Soil is a natural part of the earth's surface, being characterized by layers parallel to the surface resulting from modification of parent material by physical, chemical and biological processes operating under varying conditions during varying periods of time".[1]

Seen from a geographical and agricultural point of view, the structure and texture of the soil and its content of mineral and organic matter are of fundamental importance; the former as it affects ease of working, susceptibility of wind erosion and drainage, capacity to absorb and retain water, power to resist erosion; the latter as it provides plant nutrients.[2]

1. Soil Forming Factors and Development of Soil

It is now commonly agreed that soil is a continuously changing function of five principal soil forming factors:

(a) Parent material - including the texture and structure of the rock-formation as well as the mineralogical and chemical composition.

(b) Topography - especially since it affects both internal and external drainage.

(c) Time - the length of time during which pedological processes have been active.

(d) Climate - temperature in particular, as well as the amount and kind of precipitation.

(e) Biological activity - plant and animal organisms.[3]

The nature and composition of the soil, the result of certain soil forming processes, depends largely on climatic conditions acting over a variety of rock materials and including the decaying matter of varying types of vegetation. Although a large number of soil Types occur the number of soil forming processes is limited. Each generally results in the development of a characteristic vertical section or soil profile. A simple profile has three distinct divisions, which are designated by pedologists as the A, B and C horizons, each of which can be subdivided

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1. Thornbury, W. D., Principles of Geomorphology, New York, 1966, p. 74
2. Cole, M. M., South Africa, London, 1960, p. 79
3. Thornbury, W. D., op. cit., p. 74
4. Cole, M.M. op. cit., p. 79

into clearly distinguishable layers. The A- horizon or group of layers lies immediately below the surface and is frequently referred to as the alluvial(washed out) layer because minerals and organic material have been removed from it by water filtration. This is followed by the B-horizon in which the washed out material is deposited; and immediately below it is the C-horizon of partially decomposed parent material. The B-horizon is sometimes referred to as the subsoil or substratum. In arid regions calcium carbonate and other salts may accumulate just below the B-horizon in a horizon designated as the Cca layer. The A and B horizons together constitute the solum (soil) and is that portion of the soil profile in which the soil forming processes have greatly modified the original materials.[5] The continued uplift of the sub-continent and the great elevation of the plateau have allowed little opportunity for soil formation so that most of the soil Types are immature or even skeletal. L. C. King also attributes the immaturity to the average level of the sub-continent not being low enough to produce the slow drawn-out accumulation of vegetable waste and related processes; and additionally suggests that the climatic conditions were not humid enough to promote rapid soil formation.[6]

2. Analysis of Soil Types

Except for the extreme south-eastern sector, which forms only a very small part of the research area, the latter receives a predominantly summer rainfall, and the percentage of the total rainfall during the summer months increases from 66% in the west to 75% in the east. The total annual rainfall follows the same pattern and increases from ± 200 mm. in the west to approximately 500 mm. and more in the east. Besides the influence of climatic conditions and the nature of the parent rock, the topography also plays an important role in the formation of soil Types. In areas of uneven relief e. g., along the edge of the Great Escarpment and that of the Second Escarpment, slopes and drainage are important and it is usual to find a succession of different soils from the hill-top to the valley, constantly repeated.[7] This sequence is known as the soil catena, and is important.

The catena consists of a group of soils within a certain soil region that have developed from the same parent rock, but have different profile characteristics as a result of the various topographical and drainage conditions under which they were formed. In this way the topographical conditions under which a catena is formed may vary from level highlands to gentle, average or steep slopes, as is the case in the research area. As a result of the varying surface and internal drainage conditions, each of these topographic settings affects the nature of the soil profile. The soil catena thus has both lithological and topographical implications.[8]

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5. Thornbury, W. D., op. cit., p. 75
6. King, L. C., South African Scenery, London, 1951, p. 22
7. Cole, M. M., op. cit., p. 79
8. Thornbury, W. D., op. cit., p. 79

The four chief soil Types in the research area are:

(a) Desert Soils

(b) Gley-like Podzolic Soils

(c) Solonetzic Soils

(d) Sandy Loam and Reddish Brown Sandy Loam on Limestone.

The latter occurs in the all-season rainfall zone of the research area.

(a) Desert Soils

i. Distribution

Desert soils are found in the following magisterial districts: Murraysburg, Aberdeen, Graaff-Reinet, Jansenville, Steytlerville, Noupoort, Middelburg, Cradock, Somerset East, Steynsburg, Maraisburg, Tarkastad, southern Adelaide, southern Fort Beaufort, south-western Victoria East, the northern half of Albany, north-eastern Bathurst and the north-western corner of Alexandria.

ii. Soil Forming Factors

Although the underlying parent rock, the surface relief and the rainfall vary considerably in these semi-arid regions, the active soil forming factors throughout the whole area remain reasonably uniform. The greater part receives a limited amount of rain during summer, when evaporation is exceptionally high, up to 250 mm. and more in January. The total evaporation figure for stations spread over the whole area ranges from 1,600 mm. to 2,750 mm. per annum. The relative humidity is at the same time very low. In the parts with a rainfall of less than 375 mm. and where the temperature is subjected to great seasonal and daily variation, soil formation is affected by the fact that the amount of evaporation is greater than that of precipitation. Chemical decomposition is consequently minimal, and the parent rock is eroded mainly through mechanical processes. Although some areas receive a rainfall of 375 mm. per annum, rainfall plays a minor role as soil forming factor,[9] and the diversity of soil Types can be ascribed mainly to factors such as temperature, parent rock and topography.[10]

The exceptionally high variation in temperature plays an important part in the crumbling away of the parent rock and can be distinguished as the dominant soil forming factor in the arid regions.[11]

iii. General Description of the Desert Soil Types

The geological formations covering the greater part of the research

9. Van der Merwe, C. R., Soil Groups and subgroups of South Africa, Government Publication, Pretoria, 1940, p. 21
10. Agro-Economic Survey of the Union (VII), Government Publication, Pretoria, 1955, p. 7
11. Van der Merwe, C. R., op. cit., p. 25

area consists mainly of shales and sandstone of the Beaufort, Ecca and Dwyka Series of the Karroo System, together with numerous dolerite intrusions in the form of kopjies and ridges.[12] Except for the southern part along the Great Fish River, desert soil occurs only where the Karroo System is found within the research area.

(i) Greyish Brown to deep Reddish Brown Sandy Loam

With this soil zone a large variety of soil Types is found, influenced mainly by the parent material, topography and to a slight extent rainfall. Of these the greyish brown to deep reddish brown sandy loam soil Type, generally known as karroo soil occurs most frequently. An almost impenetrable limestone layer about 15 to 20 and more cm. thick forms the underlying formation in most instances. While this soil Type is rich in lime and potash, it is characterised by a low organic content, and a lack of phosphate and nitrogen.[13]

(ii) Light Brown Sandy Loam

In the valleys and parts with a gentle, undulating surface relief, the soil consists of light brown sandy loam about 15 cm. thick, without the presence of any carbonates. Underlying this is a layer, about 20 cm. thick, of light reddish brown, hard sandy loam, fairly well cemented by siliceous material. Underlying the latter layer is a greyish brown sandy layer, about 50 cm. thick; this is partially cemented by calcium carbonates, fairly compact, with a foundation layer of sandy loam, crumbly and mixed an appreciable amount of powdery calcium carbonate on partly decomposed rock.[14]

(iii) Alluvial Soils

Deep grey sandy loams, also known as alluvial soils, are found in narrow strips along the rivers, e. g., the Sundays and Great Fish Rivers.[15] On the whole, this soil is rich in organic content and extremely well suited to agricultural purposes where irrigation is effected.

(iv) Shallow Reddish brown stony soils with a heavier texture than the sandy loam soil of the Karroo, are found in the 'Noorsveld' in the vicinity of Jansenville.

(v) Black and Red Clay Soils

On the undulating ridges, big areas of very shallow, light brown sandy soil, mixed with stones, occur. On dolerite hills with steep slopes

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12. Agro-Economic Survey of the Union (VII), op. cit., p. 7
13. Farming in South Africa, August, 1933, p. 313
14. Van der Merwe, C. R., op. cit., p. 25
15. Ibid., p. 25

the surface is generally strewn with fragments of that rock and no soil occurs.[16] Where the dolerite intrusions occur elsewhere, the rock decomposes to form upon its outcrops fertile black and red clay soils. The drawback in this soil Type is that it occurs in patches in the immediate vicinity of the dolerite intrusions.

iv. Fertility and Use

As a result of the relative infertility of the soil and the aridity of the environment, the farming activity in the parts where desert soil is found, is predominantly pastoral in character. Sheep and goat farming are the usual occupations. Cattle are found where irrigation water is available for the cultivation of additional fodder.

Where irrigation is applied, the seasonal mountain streams are used to advantage. Under the prevailing climatic conditions, dry-land cultivation justifies only the production of fodder, while the production of grain for market purposes is not recommended at all.[17] In the low-lying parts, which have a lower rainfall, the soils are in general very shallow and supply grazing that cannot be compared with that of the rest of the Mountain Karroo.

In general the veld has a low carrying capacity, because it is periodically subjected to severe drought. In order to stablilize the agriculture, drought-resistant fodder such as spineless cactus and Australian saltbush have been cultivated.

Some important irrigation schemes, i. e. those along the Sundays and Great Fish Rivers, are found in this arid region. Here there is particular concentration on the cultivation of fodder, chiefly lucerne for sheep farming and to a lesser extent for dairy cows, and the cultivation of fruit (deciduous fruit and citrus).[18]

(b) Gley-like Podzolic Soils

i. Distribution

The Gley-like Podzolic soils of the research area consist of two sub-groups:

(i) High Veld Prairie Soils,
(ii) Semi-Coastal Belt of the Eastern Province Soils.

The former cover only a very small area of the magisterial districts of Maraisburg and Tarkastad. The latter sub-group is found especially along the Winterberg orographic region and covers the central and northern part of Adelaide, Fort Beaufort, Victoria East, Stockenström as a whole, and central-western Bedford. To the south it also occurs

16. Ibid., p. 25
17. Ibid., p.78
18. Van der Merwe, C.R., op.cit., p.299

widely in southern Albany and the north-western corner of Alexandria.

ii. Soil Forming Factors

Along the eastern boundary of the research area, where the rainfall is higher, the soil forming factors are more active and the soil forming processes are controlled by a combination of warm days and cold nights in winter and relatively high temperature and thunderstorms in summer. The thunderstorms cause the more soluble mineral constituents to be sporadically leached out, and the high summer temperature gives rise to rapid organic decomposition. Although the dry winter months bring the process of leaching out to a halt, the temperature is not low enough to stop organic decomposition completely.

Under these conditions a soil profile develops with an A-horizon, consisting of sandy loam, lacking in humus and with most of the mineral constituents leached out of it; this overlies a B-horizon of impervious mottled clay in the upper portion of which are ferruginous concretions. These concretions have formed as a result of intermittent water-logged conditions following rains, when the iron oxide compound become highly mobile. Thus some features of the B-horizon are indicative of a gleying process but, on the other hand, the higher percentage of lime compared with that in the A-horizon is suggestive of podzolization.

iii General Description of Gley-like Podzolic Soil Types

(i) High Veld Prairie Soil

This soil Type developed in the eastern areas of the Plateau, is deeper than the other Gley-like Podzolic soils, and consists mainly of an A-horizon of fine sandy laom and a clay-like B-horizon. In spite of the leaching out, the A-horizon contains limited amounts of potash and phosphate which makes the cultivation of a variety of crops possible. In general this soil is deep and the horizons are well developed. In cases of poor veld management and overgrazing, erosion has reached serious dimensions.

(ii) Semi-Coastal Belt of the Eastern Province Soils

Although Van der Merwe charted the area in the vicinity of Grahamstown, Riebeeck East and the Suurberg as desert soil, the higher rainfall does, in fact, cause the development of Podzolic soils with a ferruginous B-horizon,where the geological formation (Witteberg quartzite) is found in this region.[19]

On the Suurberg the soil profile is not well developed, and the surface soil of the highlands consists of grey loam sand with a depth of 60 cm. Along the slopes the soil has a somewhat heavier texture and is of a brownish colour. In the vicinity of Riebeeck East and Grahamstown the ferruginous horizon is better developed on the highlands, although its occurrence would seem to be patchy.

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19. Agro-Economic Survey of the Union (VII), op. cit., p. 230

The soil Types of the Winterberg, Elandsberg and the Amatola range fall under the immature or skeletal class, as a result of the removal of soil material by floods, before it has been exposed to the soil forming factors for a long enough time. Along the gently undulating northern slopes of the Amatola range, grey sandy loam soil of a depth of 45 cm. is found. On the dolerite hills the soil consists of reddish brown loam.

On the crests of the mountains near Hogsback, the soil has a doleritic origin, and is classified as dark brown clay loam. To the west, on the crest and high up the slopes of the Winterberg, dark brown clay loam, rich in humus, occurs, reasonably shallow when it is derived from dolerite. Where derived from sandstone, however, shallow sandy brown soil mixed with stone fragments occurs.

In the valleys of the rivers and their high mountain tributaries, three types of soil are common:

i. A residual topsoil varying between a grey loam and clay loam, derived from the Beaufort strata.

ii. The deep, grey alluvial soils ranging in texture from sandy loam to clay loam.

iii. A reddish brown loam to clay loam topsoil derived from dolerite, with clay loam to clay as sub-soil.[20]

The hilly area to the south of the Winterberg and in the vicinity of Adelaide, Fort Beaufort and Alice is underlain by rock of the Beaufort Series in which dolerite intrusions occur. Where the topography is favourable, a normal soil profile of from 20 to 45 cm. has developed on the shale. In the uncultivated form the soil has a grey-brown, fine sandy loam appearance. The texture becomes heavier as depth increases.

iv Fertility and Use

The soils at the foot of the Winterberg are suitable for general agricultural purposes, and are fairly well supplied with lime and potash. There is, however, a lack of phosphate. The residual and alluvial soil is used for the cultivation of tobacco in the upper reaches of the Kat River valley. In the vicinity of Adelaide, Fort Beaufort and Alice the soil Types are tilled with difficulty as a result of a layer of shale fragments and shaly gravel derived from the Beaufort beds. Agriculture is thus only found on the alluvial soil along rivers, where mainly fodder - chiefly lucerne - is cultivated.[21] In the Fish River thornveld region, also known as the area south of the Winterberg, alluvial deposits along the rivers are quite intensively cultivated under irrigation. In general this is chiefly a cattle, sheep and goat region.

In the Suurberg region and in the vicinity of Grahamstown, where

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20. Agro-Economic Survey, (III) p. 58
21. Els, W. C., Die Evolusie van Grondgebruik in die Groot-Visriviervallei, Ongepubliseerde D. Litt. et Phil. Proefskrif, Universiteit van Suid-Afrika, 1965, p. 88

the rainfall is higher, crops play an important role. Where the topography permits it, and where deeper soils occur, dry-land cultivation is successfully applied and a variety of plants are cultivated. Where alluvial soils occur, irrigation is also applied. This strip is also suited to sheep, cattle and dairy farming, and to a lesser degree fruit.[22]

(c) Solonetzic Soils

i. Distribution

In the Cape Province this soil Type is found mainly in the vicinity of Burgersdorp and Queenstown, and covers only a very small part of the research area, viz., the eastern boundary of Tarkastad.

ii. Soil Forming Factors

In the north-eastern portion of the Cape Province, where the rainfall averages between 370 and 500 mm. the soil profiles show the transition from semi-arid to sub-humid conditions. Here over the level plateau underlain by Karroo sandstones and shales the rainfall is sufficient to cause some leaching, but alkali accumulation takes place during the long dry periods and Solonetzic soils have developed.[23]

iii. General Description of Solonetzic Soil Types

These soils are unique in their sharp distinction between the A and B horizons. The former comprises a porous grey sandy loam which readily breaks up under slight pressure; the latter is darkish-brown clay, which on drying contracts into lumps readily broken into clods.

The Solonetzic soils are of very limited value for agriculture. They are excessively light and droughty and are liable to erode badly. The light sandy surface soil is readily blown by the strong winds while the abrupt change from the sandy material of the A-horizon to the clay of the B-horizon is very conducive to gully erosion.[24]

(d) Sandy Loam and Reddish Brown Sandy Loam Soils

Although the soil Types of the south-eastern Cape Province are classed with the winter-rainfall area, it is important to note that rainfall is here not limited to the winter months exclusively, but occurs as gentle rain throughout the year. The amount of rain is, however, dependent on the local relief and distance from the sea, and ranges from 300 to 675 mm. Since an intensely wet period during the year does not occur here, the leaching of the soil is comparatively low, and the main soil forming factors are the type of underlying geological formation and the covering of vegetation.[25]

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22. Van der Merwe, C. R., op. cit., p. 301
23. Cole, M., op. cit., p. 81
24. Ibid., p. 81
25. Cole, M.M., op. cit., p. 90

i. Distribution

These two soil Types are found only along the coast in the magisterial districts of Alexandria and Bathurst, where the Uitenhage and the Alexandria Series occur.

ii. General Description of the Soil Types

On the Uitenhage Series heavy reddish brown soils have developed, with sub-layers that are closely related to the underlying geological formations. The normal profile consists of reddish clay-like loam. The subsoil is red-brown grainy clay with a slight watertight appearance. The thickness of these soil layers ranges from about $2\frac{1}{2}$ m. in depth and is seldom less than 1 m. In the areas that are still densely wooded the upper soil layer has a comparatively dark appearance as a result of the accumulation of humus. This forest soil (bosgrond), as it is locally known, is frequently carted to the fields under cultivation to increase the fertility. Where the natural vegetation is meagre and consists chiefly of succulents and Karroo-bush, the formation of organic material is slight and the topsoil has a lighter colour.[26]

To the east of the Sundays River, and in the parts with a more favourable drainage, red-brown sandy loam soils have developed on the Alexandria beds; elsewhere the soil is grey-brown in colour and more sandy.[27] The subsoil varies with the thickness of the Alexandria beds. Where the soil layers are thick, the subsoil consists of sandy loam, mixed with fragments of limestone and clay loam, where it occurs as a thin layer over the Bokkeveld Shale.[28]

Along the various valleys alluvial deposits that range from rough sand to fine sandy loam occur. The parent rock is derived from the Karroo Series to the north, and contains a high ratio of alkaline salts that are not leached out under the prevailing climatic conditions. In general this soil is of a good structure and fertile. Careful and considered cultivation of the soil is, however, required to forestall the danger of brackishness on the lands under irrigation.[29]

To the south of Alexandria large fossil dunes occur, trending east west. These dunes are usually covered by dense bush and the soils derived from them are deep dark red sandy loams which are extensively used for pineapple and chicory cultivation. In addition there is a strip of dunes along the coast also covered with dense bush, and consequently a fair amount of organic material is found up to a depth of 45 to 60 cm. Where this dune sand has been blown over the shale soil it has resulted in a greyish layer of sandy soil that is found up to a distance of 3 kilometres inland. This layer of sand is up to 38 cm. thick and although it is covered by dense vegetation, it is occasionally subjected to violent wind-erosion. Only rarely is this soil used for agricultural purposes.[30]

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26. Ibid., p. 90
27. Agro-Economic Survey of the Union (VII), op. cit., p. 47
28. Cole, M.M., op. cit., p. 90
29. Ibid., p. 90
30. Agro-Economic Survey of the Union, (VII), op. cit., p. 47

iii. Fertility and Use

In the magisterial districts of Bathurst and Alexandria, pineapples, chicory, citrus, deciduous fruit, fodder and grain are cultivated. Except for the soil Type next to the coast, this land is fairly extensively cultivated.

3. Soil Erosion

(a) Natural Erosion

It is somewhat paradoxical that the threat and dimensions of erosion are greater in the arid and semi-arid regions of the country than in regions of higher rainfall. Rain falls rarely, but with a high intensity. The thin, stony ground is inadequately protected; it is but lightly bound by vegetation. Thus there is little to impede the process of erosion.[31] Geological weathering is a slow, natural process which transforms rock into soil. In the course of centuries it has carved the natural landscape into its present form. Viewed in its entirety, it is a beneficial process which maintains the balance between the formation and erosion of soil.[32]

(b) Accelerated Erosion

Accelerated erosion stands opposed to the process of natural erosion; precipitated by human activity, it is purely destructive in nature. This form of erosion is a direct consequence of man's indiscriminate exploitation of the soil. Although it is not a new phenomenon, its most widespread damage has appeared during relatively recent years in the more progressive countries; it is in direct relation to accelerating industrial expansion.[33] "The health and fertility of the soil cannot be separated from the vegetation cover; the relationship is so intimate that we cannot harm the one without harming the other."[34] The supreme importance of vegetation influences all other branches of soil conservation. Its value cannot be overemphasised. The first stage of accelerated erosion is the devastation of vegetation cover by man. It is this process which lends the elemental forces of sun, wind and water the necessary impetus to triumph in their ceaseless assault on the earth's surface. Although soil erosion can be seen as an eternal natural process, it is a process that is accelerated by man's activities to such an extent that the balance between erosion on the one hand and soil formation on the other, is disrupted.

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31. Whitmore, J. C., "The Influence of climatic factors in the Agricultural development in South Africa", South African Geographical Journal, Vol. 53-41, 1957, p. 20
32. Ross, J. C., Soil Conservation in South Africa, Department of Agricultural Technical Services, Pretoria, 1963, p. 12
33. Ibid., p. 12
34. Report of the Desert Encroachment Committee, Government Printers, Pretoria, 1951, p. 8

(c) Period of Soil Exploitation

The rapid growth of the farming sector, particularly during the last 50 years, has imposed ever-increasing demands on the country's soil. The whole agricultural pattern has suffered a dramatic change. The majority of farmers had to switch to a far more intensive agricultural programme, largely without previous experience. At the beginning of the century, through the lack of organised agricultural services, they had to rely on their own ingenuity.

"The pattern of farming was guided by market demands rather than by soil demands and all the emphasis was placed on production, with little regard to the permanence in farming."[35] Soil exhaustion and deterioration of the veld followed as an inevitable consequence, and in its wake widespread erosion appeared. In the more arid parts of the country, and especially in the Karroo, the farming of meat and wool resulted in soil erosion largely because valuable natural grazing was totally destroyed by overstocking. Apart from this devastation of plant life, soil and humus, the extent of soil erosion in these areas is so vast that the larger irrigation dams are in imminent danger of silting up from unconsolidated topsoil being washed into them.

The problem that confronts us today is the result of an agricultural system which has exploited the soil indiscriminately, which concentrates all its efforts on production, and which has paid but meagre attention to conservation. The chief causal factors of this particular system of agriculture can be summed up briefly as follows:

i. Misuse of natural veld by indiscriminate burning; maintaining herds and flocks which are too large; and poor management. The natural vegetation has consequently declined both in growth and quality, and the soil has been increasingly exposed to the ravages of wind and water.

ii. Unenlightened agricultural practices, particularly in the marginal regions of the country, where cultivation is usually rather risky.

These two factors obtain in the research area and have identical consequences: the soundness of the soil is undermined slowly but surely; productivity deteriorates; the healthy structure of the soil is demolished, and rapid erosion sets in.

(d) Precautionary Measures

The first official report on drought conditions and soil erosion in South Africa was published as early as 1926. One of the foremost recommendations of this commission was that "the State was obliged to take action in connection with soil erosion, for if erosion were allowed to continue unchecked, it would lead to national ruin".[36] In 1941 pilot

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35. Ross, J. C., op. cit., p. 11
36. Ibid., p. 15

legislation about soil erosion and related problems was initiated in the 'Bos-en Veldbewaringswet' (Act No. 13 of 1941). In 1945 the 'Soil Conservation Act' (Act No. 45 of 1945) was passed, to be supplemented in 1960 by the 'Soil Conservation Amendment Act' (Act No. 37 of 1960).

This legislation is undoubtedly one of the milestones in the agricultural history of South Africa. It paved the way for fruitful co-operation between the State and the farming community in their common goal of arresting soil erosion, and of putting agriculture on a sound and permanent footing.

The construction of weirs and contour banks should be actively encouraged. These measures have, however, not been uniformly successful. Generally they proved to be no more than precautionary measures, as they only succeed in checking the further movement of soil that has already been eroded. "Our main efforts should be to prevent soil from ever starting to move, and that can be done most effectively by vegetation".[37]

However serious soil erosion might be, one should bear in mind that it is a consequence of a more radical problem, that is, the retrogression of natural vegetation.

4. Alkali Soils

The term 'alkaline' may be applied to soil of which the soluble salts content is high enough to be detrimental to cultivating vegetation.[38] A common phenomenon of Karroo soils is that salts accumulate in the topsoil.[39] This also occurs in fairly dry areas where irrigation is practised. The high rate of evaporation, coupled with repeated irrigation, cause the soluble salts from the deeper soil layers to travel upwards by capillary action to lodge near the surface. Using water with a high salt content in irrigation may also be a contributing factor in salt accumulation.

(a) White Alkali (Witbrak)

In most cases the salts consist of sodium chloride and sulphate, and various combinations of calcium and magnesium together known as white alkali. These salts are neutral in reaction. They do not impede the natural drainage of the soil. Consequently they may be removed with relative ease from the soil by using pure water for irrigation, and by constructing artificial drainage canals to drain off dissolved salts.[40]

(b) Black Alkali (Swartbrak)

This soil Type is more harmful than white alkali. It occurs

37. Report of the Desert Encroachment Committee, op. cit., p. 8
38. Ross, J. C., op. cit., p. 56
39. Whitmore, J. S., op. cit., p. 20
40. Ross, J. C., op. cit., p. 57

when sodium carbonate is found in large quantities. Black alkali is associated with soil showing an alkaline reaction. It is extremely detrimental to the structure and drainage of the soil. The excessive incidence of sodium ions tends to decompose the loam structure of the soil. It creates clayey impermeable conditions which render the soil impenetrable to water, and natural drainage practically ceases. For this reason the accumulated salts cannot readily be drained off with the use of pure water, as they can in white alkali soils.

In the case of black alkali the first step to improve drainage would be to apply gypsum (a few tons per hectares). This application induces the sodium in the soil to be replaced by calcium ions, and this in turn rebuilds the soil structure and renews internal drainage. Once the gypsum treatment is complete, the same procedure as for white alkali may be followed.[41]

The project of placing under irrigation a further 80,000 hectares situated in the research area along the Fish and Sundays River valley is envisaged once the Orange River Project has been completed. "In the planning of an irrigation project, it is therefore essential that measures be instituted to minimize the danger associated with the subjecting of arid soils to localized humid climatic conditions ... water brings about a chemical decomposition of primary minerals which were not affected by mechanical weathering; chemical changes are accelerated and latent salts become mobile."[42] The experience gained from established irrigation schemes in the past, and present research into soil and water, must combine to bridge and overcome both present and future problems.

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41. Ibid., p. 57
42. "The Orange River Project", S. A. Council for Scientific and Industrial Research, Ref. W. 12/6/3/1/1, Pretoria, Sept., 1966, p. 18

E. CLIMATE

1. Factors Controlling Climate in South Africa in General

For a better understanding of the climate of the research area it is probably desirable to take a brief look at the factors that influence the climate of South Africa.

(a) Latitude

The amount of sun that a particular place receives is determined primarily by its latitude. Although very few facts are available at present, it is nevertheless possible to give an approximate idea of the distribution.

The total amount of radiation (T) attains a maximum in the western interior and a minimum on the east coast, while the opposite is true in the case of diffuse radiation. This condition is to be expected seeing that the general atmospheric condition in the interior is that of dry, almost cloudless sky, letting through a great deal of the sun's energy, while humid and overcast conditions prevail in the east; consequently less solar energy reaches the underlying surface there. Because of vapour and clouds, a relatively large amount of it is received in the form of diffuse radiation. This general condition is, however, subjected to very clear seasonal changes in the general atmospheric conditions.[1] In respect of the research area there is a similar difference between the cloudless western and northern parts and the overcast conditions in the south.

(b) Position

The position of the land with reference to the cold Benguela current on the west coast and the warm Agulhas and Mocambique currents on the east coast, is climatologically of cardinal importance. It is further important to note that the tapering sub-continent of Africa is only 1,300 kilometres wide at 30° S and therefore does not have marked continental climatic conditions. Compared to Australia, with a width of 3, 800 kilometres on the same latitude, South Africa stands very much under the moderating influence of sea air.[2]

(c) Height above Sea Level

It is sufficient to say that the main feature is a high plateau of approximately 1,000 m. in the centre (Kalahari region), which becomes higher peripherally and culminates on the eastern perimeter in the Great Escarpment that reaches a height of more than 3,000 m. in Lesotho. From the escarpment there is an abrupt fall, sometimes in the form of terraces, down to the coast. These physical characteristics, and in particular the escarpment that divides South Africa into two morphological areas, have a profound influence on the climate in general.[3] The complicated mutual interaction of contrasting air masses and the presence of the escarpment contribute to the weather conditions of any area in South

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1. Weather Bureau Publication, Climate of South Africa, General Survey, Part 8, W. 28, 1965, p. 15
2. Ibid. p. 1
3. Ibid. p. 2

Africa, and lead to a marked discontinuity between the circulation over the two main physiographic regions.[4]

Depending upon the differences in radiation at different latitudes and relationships between land and sea, the following secondary factors are: [5]

(d) General Circulation of the Atmosphere

The climate of any place on earth is determined by two further factors, viz. the planetary circulation of the atmosphere and, the influence of local factors on the former. The sub-divisions of the circulations are the following:

i. primary or planetary circulation,

ii. secondary circulation that occurs within the planetary circulation (with regard to South Africa it is the circulation around normal high and low pressure cells that is of importance), and

iii. tertiary circulation, consisting of winds caused by local differences in temperature, generally known as land and sea breezes, berg winds, and katabatic and anabatic winds.

"It has been customary to explain the contrasting seasonal climates of most of South Africa, with their general wetter summers and drier winters, as the consequence of a monsoonal reversal of pressure and winds. Thus, the sea level pressure charts show a trough of low pressure over the interior plateau in summer and an anticyclone in winter. But the winds at the plateau level do not conform to this pressure reversal, for there is no evidence of a cyclonic wind system in summer. The seasonal pressure charts for January and July are essentially similar, both showing isobaric arrangements that are anticyclonic. This pattern is in reasonable agreement with the observed wind systems. Thus, the persistent pressure distribution over the South African plateau is anticyclonic, but somewhat weaker in summer than in winter, when the cell moves northwards bringing the surface westerlies over the southern-most parts of the continent."[6] During winter the high pressure over the land increases, while there are indications of a weak equatorial low pressure tongue over the interior in summer.

In summer this high pressure cell lies further east and is centred off-shore; with an anticyclonic air movement, the result is that warm, humid air flows into the land. Should the high pressure cell be over the south of Mocambique, maritime-tropical warm air is driven inland. Should this high pressure cell be over the northern part of this area, maritime equatorial warm air would be driven inland. This circulation goes

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4. Cole, M.M., South Africa, London 1966, p. 32
5. Trewartha, G.T., The Earth's Problem Climates, London, p. 139
6. Weather Bureau Publication, W.B. 28, p. 1

hand in hand with north-easterly, northerly and north-westerly winds that give rise to summer rains over the greater part of South Africa. This weather condition very often synchronises with the arrival of maritime cold air from a southerly or south-easterly direction, which is caused by small high pressure cells that move in an easterly direction to the south of the Cape and absorb vapour over the warm Agulhas and Mocambique currents.

This southern and south-eastern humid air causes orographic rain over the escarpment.[7] The concurrence of these two contrasting air masses further causes the humid maritime tropical air from the north and north-east to be pushed up by the cold maritime tropical air from the south and south-east, and continuous heavy rains or general thunderstorms occur over the Cape Midlands and Karroo regions. The intensity of the precipitation depends on the humidity and stability of the tropical air.

During winter it is particularly the following pressure systems that have an important effect on the climate of South Africa. "A weak anticyclone dominates the South African plateau at all times of the year, although the high pressure moves northwards in winter."[8] With the high pressure cell over the Transvaal, dry continental warm air is found over the greater part of the Republic, and mainly blows from a northerly direction. The succession of depressions and anticyclones having their origin in the southern polar front, affects the south-western and southern tip of the continent. The eastward movement of depressions, which are further to the north during the southern winter, contributes greatly to the variable climate of these parts, with an increase in intensity towards the coast. The winter rainfall area and the south and east coast have rain during the winter months as a result of cold fronts that approach the land from the south-west. These frontal low pressure cells are coupled with north-west winds that gradually increase in strength as the system develops. Once the cold fronts reach the land, soft rains will begin and gradually move to the east. Bitter cold is at times experienced, particularly in the Cape, when maritime Antarctic cold air penetrates the interior as south-west winds. Accompanying this cold, snow normally occurs on the southern and eastern escarpment and on the Winterberg-Amatola range.

(e) Ocean Currents

The surface temperature of the oceans is an important factor in the conditioning of the air masses that exercise influence on the sub-continent. The difference between air and sea surface temperature in our seas varies from 0.5 and 1° C in summer to about 2° C in the winter. A further important phenomenon of the average air temperature over the sea during January and July is the exceptionally great temperature anomaly that is caused by the warm Agulhas and Mocambique current on the east and south coast on the one hand, and on the other the cold Benguela current on the west coast.

Another important factor in connection with sea temperature influencing climate, is the fact that maximum temperature in terms of maximum solar radiation (summer solstice) is attained much more slowly over the sea than over the land.

7. Official Yearbook of the Union of South Africa, No. 30, 1960, p. 18
8. Board, C., The Border Region, Cape Town, 1962, p. 41

Other factors that influence climate to a lesser degree are:

(f) The general nature of the underlying surface (soil type, water, snow, ice),

(g) Vegetation,

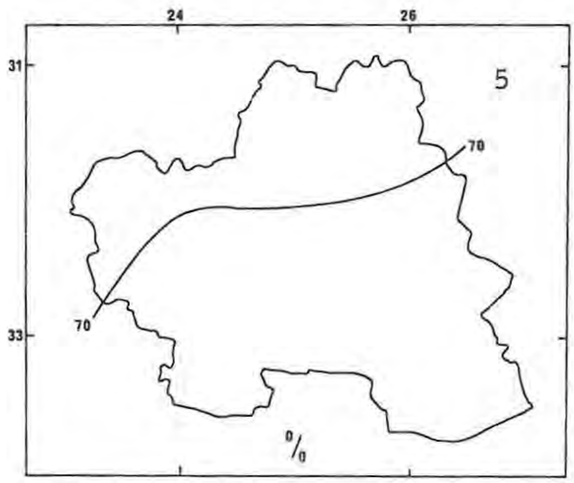
(h) Orientation in terms of ridges and hills, which often give rise to micro-climatic differences.

2. Climatic Elements Considered in Particular with Respect to the Research Area

(a) Sunshine

Since 1950, many more stations have been equipped with sunshine meters. As far as the research area is concerned, data is available only for the following three observation stations: Bathurst, Jansenville and Grootfontein.

The mean annual duration of bright sunshine, expressed as a percentage of the (astronomically) possible duration, is as follows: to the north of about 32° S latitude, the mean annual duration is between 70% and 80%, and to the south of this latitude, as far as the coast, from 60% to 70%.



MAP 5 : MEAN ANNUAL DURATION OF BRIGHT SUNSHINE*

It appears that orographic features with their effect on cloud formation, play a large part in the distribution of sunshine, and in the mountain ranges, particularly in the southern Cape Province and along the coast, the annual duration of sunshine may be in the region of 50% or lower.

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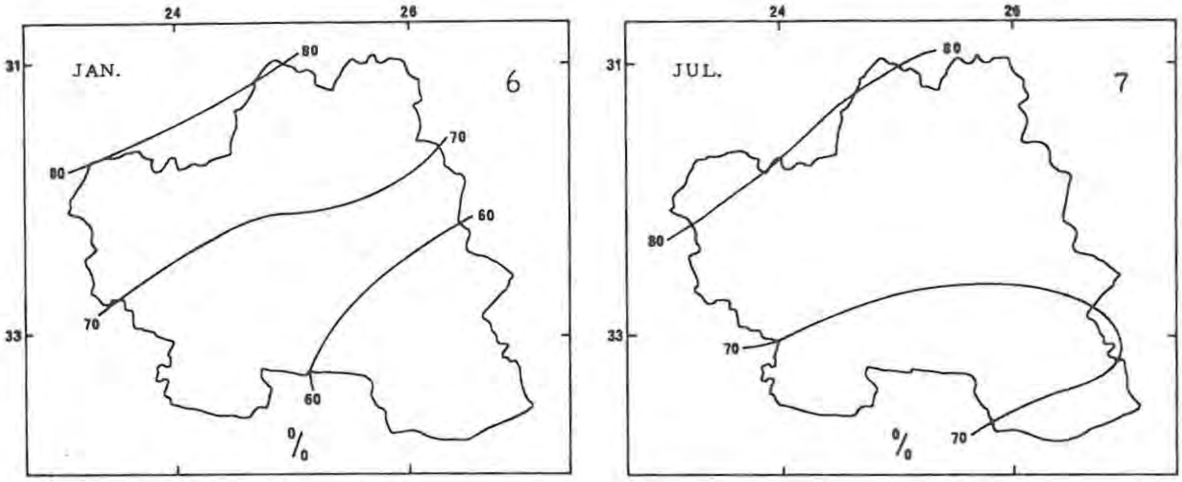
* Adapted from Weather Bureau Publication, Sunshine and Cloudiness in S.A., W.B. 14

From Maps 6 and 7, which give the mean duration of sunshine, expressed as a percentage of the possible sunshine, for the months January and July respectively, the following can be deduced with regard to the seasonal distribution:



MAPS 6 AND 7: MEAN MONTHLY DURATION OF BRIGHT SUNSHINE *

i. The region of maximum duration of sunshine moves northwards in winter and southwards in summer.

ii. The zone of minimum duration of sunshine during summer (60-70%), is found in the south-eastern corner of the research area, and during winter (70-80%) over the southern part, except for the parts along the coast.

The mean monthly and annual duration of sunshine (hours) and frequency for Jansenville, Bathurst and Grootfontein are summarised in Table 2. With regard to the annual march of sunshine, the research area falls under section 5 (as demarcated by the Weather Bureau) and shows a double period. The two minima at the coast are usually in February-March and October-November. The percentages for Bathurst in February-March are 57% and 53%, and 50% and 54% for October-November. In the case of Bathurst, the figure for April (53%) is lower than that for March. Over the interior the minimum periods fall in April and September, so that at Grootfontein for example 72% and 76% respectively of the possible duration are experienced in those months. The percentage possible duration of sunshine shows a definite increase during the winter months and a decrease during the rainy season (summer months). At the coast the annual variation is about 15%, and this decreases to 10% over the interior.

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* Adapted from Weather Bureau Publication, Sunshine and Cloudiness, W.B. 14

Month-Maand	Mean Daily Hours Gem. Daaglikse Ure	% of Possible Duration % v.d. Moontlike Duur	No. of days with: / Getal dae met: No Sunshine Geen Sonskyn	1-10% of Possible v. Moontlike	11-49% of Possible v. Moontlike	50-89% of Possible v. Moontlike	90-100% of Possible v. Moontlike
GROOTFONTEIN (260 Kilometres from the sea)							
J	10.4	75	0.8	1.4	2.8	12.7	13.3
F	9.4	71	0.4	1.0	4.1	13.7	8.8
M	9.0	73	0.2	0.9	3.2	17.2	9.5
A	8.2	72	0.6	1.3	3.2	19.1	5.8
M	7.7	73	0.2	0.9	3.6	19.6	6.7
J	8.0	79	0.6	0.8	2.0	14.6	12.0
J	7.6	74	0.6	1.0	3.3	23.2	2.9
A	8.6	78	0.6	0.8	1.0	20.2	8.4
S	9.1	76	0.2	0.5	3.4	15.0	10.9
O	9.7	76	0.1	0.5	4.2	15.1	11.1
N	9.3	68	0.7	1.3	5.1	13.4	9.5
D	10.7	76	0.1	0.1	3.9	12.9	14.0
Year Jaar	9.0	74	5.1	10.5	39.8	196.7	112.9
JANSENVILLE (120 Kilometres from the sea)							
J	9.9	71	0.6	0.1	3.9	20.9	5.5
F	10.0	75	0.2	0.5	2.0	16.0	9.5
M	7.7	62	1.6	1.2	5.4	19.2	3.6
A	7.7	69	0.6	1.4	4.4	16.2	7.4
M	6.8	65	1.0	1.4	5.6	17.4	5.6
J	7.2	75	0.2	0.4	3.3	18.4	7.7
J	7.2	70	0.4	0.8	5.6	16.2	8.0
A	8.1	75	0.2	1.0	2.9	17.0	9.9
S	8.2	69	0.8	0.8	3.6	22.6	2.2
O	8.9	69	0.6	1.0	5.4	19.2	4.8
N	9.7	70	0.8	0.4	4.6	16.6	7.6
D	9.5	66	0.8	1.2	5.1	15.5	8.4
Year Jaar	8.4	70	7.8	10.2	51.8	215.2	80.2
BATHURST (12 Kilometres from the sea)							
J	8.2	58	0.9	1.4	9.4	16.4	2.9
F	7.6	57	1.4	1.5	7.9	13.6	3.6
M	6.6	53	0.2	3.2	10.2	16.2	1.2
A	5.9	53	5.2	2.2	6.2	10.2	6.2
M	6.3	61	2.2	4.2	3.2	18.2	3.2
J	7.5	75	0.2	0.3	3.3	25.4	0.8
J	7.1	70	0.6	1.6	4.1	17.1	7.6
A	7.9	72	1.1	0.1	3.6	17.6	8.6
S	7.3	61	0.5	1.5	6.0	21.0	1.0
O	6.5	50	1.6	2.6	7.6	18.1	1.1
N	7.5	54	1.0	3.0	8.5	14.0	3.5
D	8.5	59	1.6	1.6	6.1	17.1	4.6
Year Jaar	7.2	60	23.2	23.2	76.1	204.9	44.3

TABLE 2: MEAN MONTHLY AND ANNUAL SUNSHINE DURATION (HOURS) AND FREQUENCIES **

** Source: Weather Bureau Publication, Climate of South Africa, General Survey, W.B. 28

At the coast this annual variation of 15% can be ascribed to the abundance of clouds at all times of the year, and over the interior mainly as a result of the absence of clouds throughout the whole year.[9]

The annual march of the frequency of occurrence of 'overcast' or 'cloudy' days is of particular importance because it has a direct influence on the effectiveness of rainfall. A high monthly frequency of full sunshine during the winter months will have an abnormal evaporation over the regions with winter rainfall, and decrease the effectiveness of the rainfall. In the interior a June with as many as 28 days with full sunshine can occur. Here there are, however, no adverse effects, seeing it is at this time of the year, the dry season, that there is no rain to suffer evaporation.

During the summer months, the situation is much more critical in the Midlands and Karroo with a predominantly summer rainfall. At this time of year the sun is at its warmest, and the high frequency of clear days and consequent high evaporation definitely has an adverse effect.

(b) Cloudiness

The observation of the amount of cloud at 0800 and 1400 hours, was only begun in 1940. In the research area data is available for only seven observation stations, according to Table 3. Since the data for 1400 hours at Great Fish Point is lacking, the data for Port Elizabeth has been included in order to give a better illustration of the difference between the interior and areas along the coast. It is further noticeable that cloudiness reaches a maximum in the morning over the winter rainfall area, while an afternoon maximum is characteristic of the greater part of the summer rainfall areas. For this reason both the morning and afternoon observations must be taken into consideration in order to present the overall degree of cloudiness.[10]

	J		F		M		A		M		J		J		A		S		O		N		D		Year Jaar	
	0800	1400	0800	1400	0800	1400	0800	1400	0800	1400	0800	1400	0800	1400	0800	1400	0800	1400	0800	1400	0800	1400	0800	1400	0800	1400
GREAT FISH POINT	5.2	-	5.3	-	5.1	-	4.6	-	4.3	-	3.4	-	3.5	-	3.7	-	4.7	-	5.3	-	5.7	-	5.3	-	4.7	-
GRAHAMSTOWN	4.3	-	4.2	-	4.2	-	3.5	-	3.2	-	2.4	-	2.8	-	3.0	-	3.1	-	4.4	-	4.4	-	3.9	-	3.6	-
JANSENVILLE	3.7	3.6	4.6	3.9	4.6	4.3	3.8	4.0	3.8	4.0	2.9	3.3	2.9	2.9	3.2	3.5	4.1	4.4	4.3	4.7	3.9	4.5	3.4	3.7	3.8	3.9
SOMERSET EAST	4.7	4.7	4.9	4.8	5.0	5.5	4.3	5.2	4.3	5.1	3.1	4.3	3.6	3.9	3.6	4.2	4.2	5.0	5.1	3.0	5.0	5.3	4.2	4.9	4.3	4.7
GRAAFF-REINET	3.7	4.3	4.3	4.7	4.4	4.7	4.1	4.7	3.9	4.3	3.2	3.7	3.4	3.5	3.3	3.6	4.2	4.7	4.7	5.3	4.7	4.7	3.5	4.3	3.9	4.4
CRADOCK	2.7	3.0	3.1	4.1	3.6	4.1	3.6	3.5	3.5	3.7	2.8	3.2	2.8	2.6	2.7	3.0	3.3	3.6	3.8	3.9	3.6	4.6	3.1	3.8	3.2	3.5
GROOTFONTEIN	3.5	4.1	3.7	4.3	3.8	3.9	3.5	4.0	3.4	3.5	2.5	3.1	2.9	2.1	2.5	2.9	3.3	3.5	3.9	4.0	3.9	4.2	3.2	3.9	3.3	3.6
(PORT ELIZABETH)	5.4	3.8	5.0	3.9	5.2	4.1	4.6	4.1	4.6	4.1	3.6	3.9	3.8	3.6	4.1	3.9	4.7	4.4	5.6	5.1	5.4	4.4	4.9	3.9	4.7	4.1

TABLE 3: MEAN MONTHLY AND ANNUAL CLOUD COVER IN TENTHS*

* Adapted from Weather Bureau Publication, Climate of South Africa, General Survey, W. B. 28

9. Weather Bureau Publication (W. B. 28), op. cit., p. 26

10. Ibid., p. 66

By comparing the data for Port Elizabeth and Middelburg, as set out in Table 3, the difference between morning and afternoon observations, as well as a decrease in cloud cover towards the interior, is made very clear. Along the coast cloudiness is caused mainly by convection and the passing of fronts.

The relation between the duration of sunshine and cloudiness is striking, and it would appear that the region of least cloudiness is moved to the north in winter, when it also spreads out. The region of maximum cloudiness is found over the east coast and eastern plateau in summer and occurs in the south-western Cape Province in winter, while there is little variation along the southern Cape coastal belt. The average cloudiness between two and three tenths in the western and central parts, and between four and five tenths in the east, with a maximum during spring and summer in all three areas.

The daily variation is better known for places along the coast than over the interior. Maximum cloudiness occurs in the early morning and evening along the coast, while the minimum is observed during the afternoon and at midnight. The summer variation is inclined to be greater than that of winter. During the summer the mornings may be overcast, clearing later in the day and becoming overcast again towards evening. In winter it is inclined to stay overcast if the morning is overcast.

(c) Humidity

Relative humidity is a direct measure of the degree of humidity of the atmosphere regardless of temperature, and indicates the percentage of the degree of saturation (100 x vapour pressure divided by saturation deficit).[11] The percentage relative humidity can be changed either by a change in the amount of vapour in the atmosphere or by a change in the temperature. The calculation of the mean annual relative humidity is based on readings taken at 1400 hours and the chief reasons for selecting this time are: lack of daily averages, differences in local time (at 0800 hours the relative humidity changes quickly, while it is constant for at least two hours at 1400 hours) and because by this time the surface air has lost its stratified nature and has become well mixed.

The relative humidity in South Africa may be readily understood if one were to suppose a homogeneous air mass over the continent all the year round. Then the relative humidity would vary inversely with the temperature. Over the eastern and north-eastern parts of South Africa there is a deviation from the hypothesis, and this is the result of the influx of moisture in the warm season being sufficient to counteract the effect of the rising temperature. The position in these regions is then such that the annual variation of relative humidity agrees more or less with that of the rainfall. The relative humidity is at a minimum or near the minimum in the cold season and at a maximum during the rainy season.

At the coast the mean annual relative humidity is about 70% (Port Elizabeth 71.8%), dropping rapidly to 50% at Middelburg. For the greater part of the research area, the mean annual range is between 10% and 20% at 1400 hours, with a tendency to decrease towards the

11. Weather Bureau Publication, (W.B. 28) op. cit., p. 196

east. Whereas the range is 11.6% in Port Elizabeth, it increases to about 20% in East London. The small play over the western interior is largely to be ascribed to the low relative humidity throughout the year. The difference between Port Elizabeth and East London is probably to be partly ascribed to the fact that East London has a higher percentage of cloudiness during summer, and to the difference in rainfall regime.

	JANSENVILLE				SOMERSET EAST				GRAAFF-REINET			
	0800		1400		0800		1400		0800		1400	
	S	H	S	H	S	H	S	H	S	H	S	H
J	7.9	69.0	27.1	38.9	7.3	67.1	23.4	36.9	8.5	65.2	27.8	34.9
F	5.6	77.0	26.9	38.0	5.3	75.2	21.4	41.0	6.7	71.1	24.1	40.9
M	4.6	78.8	22.0	41.7	4.6	77.0	18.7	44.0	5.5	74.2	21.6	41.1
A	3.8	78.2	19.0	40.8	4.4	73.2	16.7	42.0	5.4	68.8	18.0	40.0
M	3.1	77.4	15.9	40.9	4.9	66.0	14.6	41.0	5.0	65.8	15.1	38.9
J	2.9	73.1	13.6	39.6	4.5	62.2	12.8	38.8	4.4	63.3	13.2	36.8
J	3.1	70.6	13.6	38.7	4.6	60.3	12.7	37.7	4.1	63.4	13.1	36.1
A	3.4	72.6	15.6	38.1	4.8	62.2	14.6	36.0	4.5	62.8	15.2	35.0
S	4.1	73.0	18.0	37.1	5.0	65.3	16.6	35.0	5.1	65.8	18.6	32.1
O	6.1	67.7	20.1	38.0	6.4	63.8	16.3	39.9	6.5	65.0	20.9	34.0
N	6.9	68.0	25.2	33.0	6.2	68.2	19.6	37.0	7.1	66.0	24.3	33.0
D	9.3	61.9	27.6	33.0	7.6	65.0	21.3	38.1	8.2	65.0	26.1	34.9
Year Jaar	5.1	71.8	20.4	38.0	5.5	67.6	17.4	39.0	5.9	66.9	19.8	36.5

	CRADOCK				GROOTFONTEIN			
	0800		1400		0800		1400	
	S	H	S	H	S	H	S	H
J	7.2	68.0	28.4	31.1	7.6	65.0	27.0	30.9
F	5.3	75.1	23.1	38.9	6.4	68.8	24.9	34.1
M	4.4	76.8	19.4	42.0	4.2	76.2	19.5	39.0
A	2.7	81.0	17.4	39.2	4.8	65.0	14.5	42.0
M	2.2	79.0	15.4	35.0	2.6	74.5	13.1	37.0
J	2.0	75.6	14.1	31.2	1.9	75.0	11.0	37.1
J	2.1	73.4	13.9	31.2	2.0	73.0	11.5	33.9
A	2.7	71.3	15.4	32.2	3.0	67.4	13.3	31.8
S	4.1	68.5	18.0	31.0	4.9	61.1	16.2	31.1
O	5.7	66.1	20.2	33.1	6.2	61.2	20.4	27.9
N	6.6	66.0	22.4	32.9	7.0	62.2	22.4	28.9
D	7.2	66.8	24.0	35.0	8.6	61.1	25.1	29.1
Year Jaar	4.3	72.0	19.3	34.8	4.9	66.7	18.2	33.4

TABLE 4: RELATIVE HUMIDITY (H%) AND SATURATION DEFICIT (S) in mb (1400 S.A.S.T.)

The saturation deficit represents the amount (in pressure units) by which the vapour-pressure falls short of saturation, and is a measure of the dryness of the air. Table 4 contains values (in mb) of saturation-deficit for 5 stations in the research area. During winter the saturation-deficit is the lowest over the whole region as a whole, since the temperature is at its lowest during this season and the possible water content of the air (saturation-vapour-pressure) is at its minimum. During summer the saturation-deficit is more than 28 mb in the north of the research area, and decreases to the south to about 10 mb at the coast. This is to be ascribed to the higher relative humidity in the south.

From Table 4 it is evident that the saturation-deficit is subject to a large diurnal variation; the values at 8 a.m., when temperature is near the minimum of the day, are very much lower than in the afternoon at 2 p.m. Since the saturation-deficit represents the amount of water that the atmosphere is still able to absorb, this clearly indicates that it would be most wasteful to irrigate (especially by spraying) during the middle of the day when temperature is high and wind velocity is at a maximum. Particularly for agriculture and on the various irrigation schemes this trend is of the greatest importance, since irrigation can be exploited with maximum effect when the saturation-deficit is at its lowest. Since the saturation-deficit is dependent on both relative humidity and temperature, the best time for irrigation is during the early morning, late afternoon or evening and on cool, overcast days.

(d) Evaporation

"Effectiveness of rainfall is usually taken as the actual rainfall minus the total possible evaporation."[12] It is thus of importance to look at the distribution of evaporation in the research area with its low rainfall. Unfortunately there are insufficient statistical data regarding evaporation available in the Karroo and Midlands in particular to correlate with rainfall data.

Evaporation of water from a moist surface or a free water surface depends on many factors such as temperature, wind and saturation-deficit of the air, and no simple relationship between evaporation and other parameters or variables exists. "Variations in the rate of gross evaporation from month to month and from year to year, are closely dependent on the variation of insolation, temperatures, wind, cloudiness and relative humidity. Evaporation is normally greatest when berg-winds are blowing and least during cloudy, cool wet periods."[13]

	J	F	M	A	M	J	J	A	S	O	N	D	Year Jaar	Summer Somer %	Autumn Herf %	Winter Winter %	Spring Lente %
JANSENVILLE	11.0	9.5	7.4	4.6	2.8	3.0	3.1	4.7	6.2	8.3	10.7	11.4	82.7	38	18	13	31
GROOTFONTEIN	11.8	10.0	8.1	5.8	4.1	3.6	4.5	6.1	7.7	9.8	11.3	11.5	94.2	35	19	15	31

TABLE 5: MEAN MONTHLY AND ANNUAL EVAPORATION (inches) FROM CLASS 'A' PANS * (1 in. = 25.4 mm.)

As is evident from Table 5, the maximum evaporation occurs during the summer months and the minimum during the winter months. As a result of the dominant temperature conditions, the maximum evaporation occurs in summer over the Karroo and Midlands, while it is at a minimum during winter for these stations in contrast with those at the coast.

According to Map 8 it is evident that evaporation is greatest in the southern interior of South West Africa and least along the eastern edge of the plateau, in the mist belt of Natal and on the southern and south-western Cape coasts. If these data for evaporation pans are meaningful, then it can be said with reasonable certainty that the maximum evaporation in this region follows the rainy season and the dominant temperature conditions.[14]

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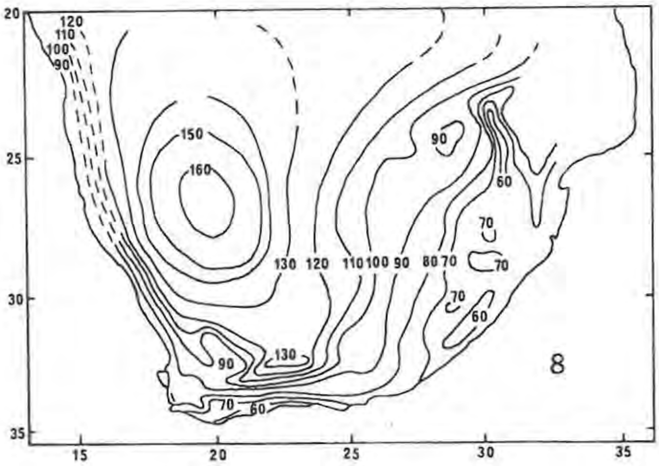
* Adapted from Weather Bureau Publication, Climate of South Africa, General Survey, W. B. 28

12. Monkhouse, F. J., and Wilkinson, H. R., Maps and Diagrams, Methuen, London, 1964, p. 149
13. Board, C., op. cit., p. 55
14. Du Toit, W. F. J., Die Fisiografie en Aspekte van Bodembenutting in die Sentraal-karoogebied. 'n Geografiese Studie na Minimum-afwykingstreke, Ongepubliseerde M. Sc. verhandeling, Randse Afrikaanse Universiteit, Desember, 1968, p. 41



MAP 8: MEAN ANNUAL EVAPORATION (in inches) FROM CLASS 'A' PANS (1 in. = 25.4 mm.)

(e) Winds

The general circulation of the atmosphere of South Africa has already been discussed in broad outline.

As regards the surface winds, one finds that the South African escarpment contributes to the fact that the development of climatic conditions is complicated and can be seen as an important climatological and meteorological boundary. The natural division of the land into coastal and plateau landscape and the observation of surface winds on both these landscapes have revealed that the circulation of air masses over the plateau is not the same as that over the surrounding countryside. Observations taken between 0800 and 1500 have shown that there is a diurnal variation in the wind direction, and it is chiefly in regard to this change in wind direction that there is a noticeable difference between the plateau and the surrounding area. "As a rule the winds prevailing in these lowlands do not reach the plateau and there is difficulty in recognising that the surface circulations in the two regions are distinct."[15]

The main seasonal differences in the wind regime are as follows:

i. Coastal Belt

In the vicinity of Port Elizabeth and East London there is a tendency for the prevailing winds to blow with an off-shore component in winter and on-shore in summer. At these two stations the frequency

15. Jackson, S. P., "Air Masses and the circulation over the plateau and coasts of South Africa", South African Geographical Journal, Vol. 27, 1947, p. 10
16. Weather Bureau Publication, (W. B. 28) op. cit., p. 234
17. Weather on the Coast of South Africa, Government Publication, Vol. II, part 3, (1942), p. 6

of the south-easterly to north-easterly winds is very much reduced in winter, the wind blowing almost entirely from the westerly and north-westerly sector.[16]

The south-coast lies in the transition zone from the South-western Cape to the summer rainfall region of the Central and Eastern sector of the country. It can also be seen as a transition zone in respect of winds; the frequency of the "southeaster" of the Cape decreases to the east, and in the vicinity of Port Elizabeth it has a frequency of about 15 per cent. By way of contrast with the Cape, the south-east winds are frequently associated with low cloud and rain in Port Elizabeth. "A combination of an intense anti-cyclone close to the coast and a deep depression over the interior may lead to a strong easterly gale and occasionally the kind of weather that is known locally as the "Black South-easter". The latter occurs in the summer only, and is preceded by the south-west wind backing to south and east. As the forefront of the anti-cyclone approaches, it brings low cumulus clouds and showers, followed later by nimbo-stratus and drizzle. This may last for several days, thickening on the coastal mountains and the escarpment."[17]

From March to May the least wind is found along the coast. At Port Elizabeth the number of calm days is more than 10 per cent for April and May, and the mean wind velocity decreases to 18 kilometres an hour. Spring is widely known as the windiest season of the year, and the wind velocity increases to a mean of between 24 and 29 kilometres an hour for the period August-October.

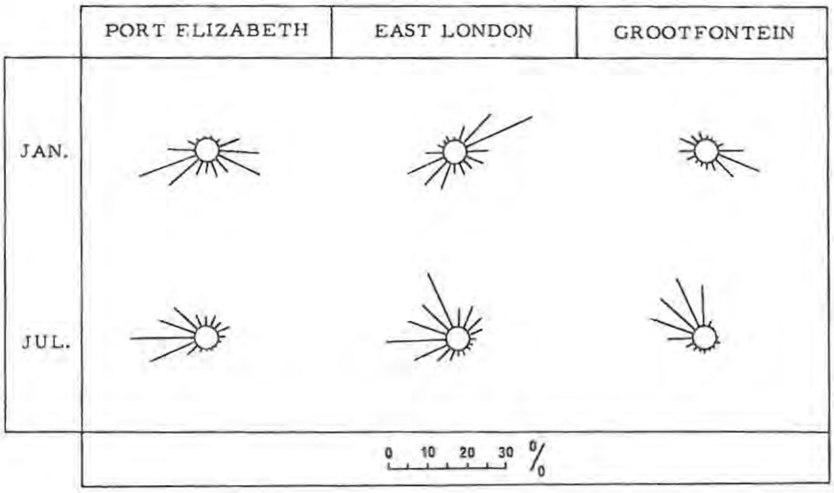


FIG. 1: WIND DIRECTION FREQUENCIES FOR (a) PORT ELIZABETH, (b) EAST LONDON AND (c) GROOTFONTEIN *

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* Adapted from Weather Bureau Publication, Climate of South Africa, General Survey, W. B. 28

16. Weather Bureau Publication, (W. B. 28), op. cit., p. 234
17. Weather on the Coast of South Africa, Government Publication, Vol. II, part 3, (1942), p. 6

ii. Interior

In the interior of the Cape Province the seasonal change in the wind is very noticeable.

At Grootfontein, situated within the eastern sector of the interior, the wind blows from east-south-eastern directions in summer, and from a north-westerly direction during winter. Compared with Ladysmith, Natal, it is noticeable that the south-easterly winds practically stop blowing at Grootfontein in winter.[18] With regard to these south-easterly winds, Tyson says: "The southeast trades are entirely absent south of Mocambique, and they have no relevance in the origin of rainfall over Natal and the Eastern Cape and the southeast winds observed over so much of the marginal lands are purely local topographic winds.[19] The local south-easterly wind over Natal is an entirely fine weather phenomenon. It is a topographically-induced thermodynamic wind conforming to a simple harmonic model with an approximately twelve hour periodicity."[20]

Local orographic features also have an important effect on the diurnal variation in wind direction. Lying at the foot of the Van Ryneveld Pass in the Sneeuberg, Graaff-Reinet has a situation favouring moderate north-western katabatic winds during early morning. It would appear that this wind's highest frequency is at the beginning of the winter season and is inclined to blow the strongest at the end of the season. This wind is normally replaced by a southerly anabatic wind later on in the day.

In the interior the autumn months are also the calmest. At Middelburg the percentage calm days rises to 35 in April. During August Middelburg experiences the strongest winds, with a daily average of 16 kilometres an hour. It is reasonably calm during the early morning, but the strength increases rapidly after 9 a.m., reaching a maximum at about the middle of the day. Spring is generally known as the windiest season, but there are considerable variations in wind speed and directions in different parts of the interior. With the onset of summer there is an increase in the frequency of south-east winds.

The abovementioned facts are all more or less reconcilable with the mean air pressure distribution and seasonal movement of the high pressure belt. During summer there is a definite indication of a surface convergence of air in the interior of South Africa, while in winter, when a strong anti-cyclonic circulation is over the country, the surface air moves from the land and indicates that a general subsidence takes place. The resultant movement of air is towards the land in summer and towards the sea in winter. These resultant surface winds suggest a barometric trough lying more or less over the Kalahari in summer, while they coincide with a simple anti-cyclonic circulation in winter.[21]

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18. Weather Bureau Publication, (W. B. 28), op. cit., p. 234
19. Tyson, P. D., "Southeast winds over Natal", Journal for Geography, Vol. III, No.3, Sept., 1968, p. 245
20. Ibid., p. 243
21. Weather Bureau Publication, (W. B. 28), op. cit., p. 240

iii. Bergwinds

During certain winter mornings there is a warm wind that apparently blows directly from the plateau in the direction of the coast. This wind is known as the bergwind and is of particular importance over the areas along the coast, where it is experienced periodically and particularly in winter and is characterised by particular warm weather. Although these bergwinds blow from the same direction as the land breezes, the former have considerably higher temperature and speed.

The bergwind is one of the best-known characteristics of the South African climate. As a result of some similarities between these winds and the Föhn and Chinook, attempts have been made to explain South African bergwinds by means of an analogy with the latter two examples. None of the explanations is entirely satisfactory.

According to Jackson it is difficult to observe the respective surface circulations over the plateau and the lowlands. There are certain observable differences that do in fact occur. It may be accepted without any doubt that the origin of bergwinds is not the result of the katabatic flow of air from the plateau on cold nights. "It is found that the departures from the mean maximum temperatures during bergwinds are of the same order of magnitude on the plateau as in the coastal regions: hence the high temperatures in the latter regions could not be due to some warming process which effects the air over the coastal regions only. The air is warm to start with and the warming is due apparently to divergence and subsidence which takes place in the free atmosphere."[22] In general the direction of bergwinds corresponds with the general circulation over the country as a whole. Bergwinds are normally associated with a high pressure cell over the interior and the advance of a depression over the sea and near the coast. The divergence normally occurs over a limited area. The sudden descent of the bergwind and the occurrence of misty and overcast conditions immediately after are in agreement with these conditions. Divergence dies down as soon as the isobars again move in a straight line - i.e. when the circulation changes from anti-cyclonic to cyclonic. The South African bergwind can be seen as the southern counterpart of the Sirocco of Sicily or the Harmattan of West Africa.[23]

(f) Rainfall

i. Rainfall Zones

In 1935 Schumann and Thompson divided the Republic of South Africa into 23 rainfall zones on the basis of the phases and relative amplitude of seasonal distribution of rainfall. They gave a table for the mean monthly rainfall for each region, expressed as a percentage value of the annual mean, as well as the percentage value for the summer (Oct.-March).[24]

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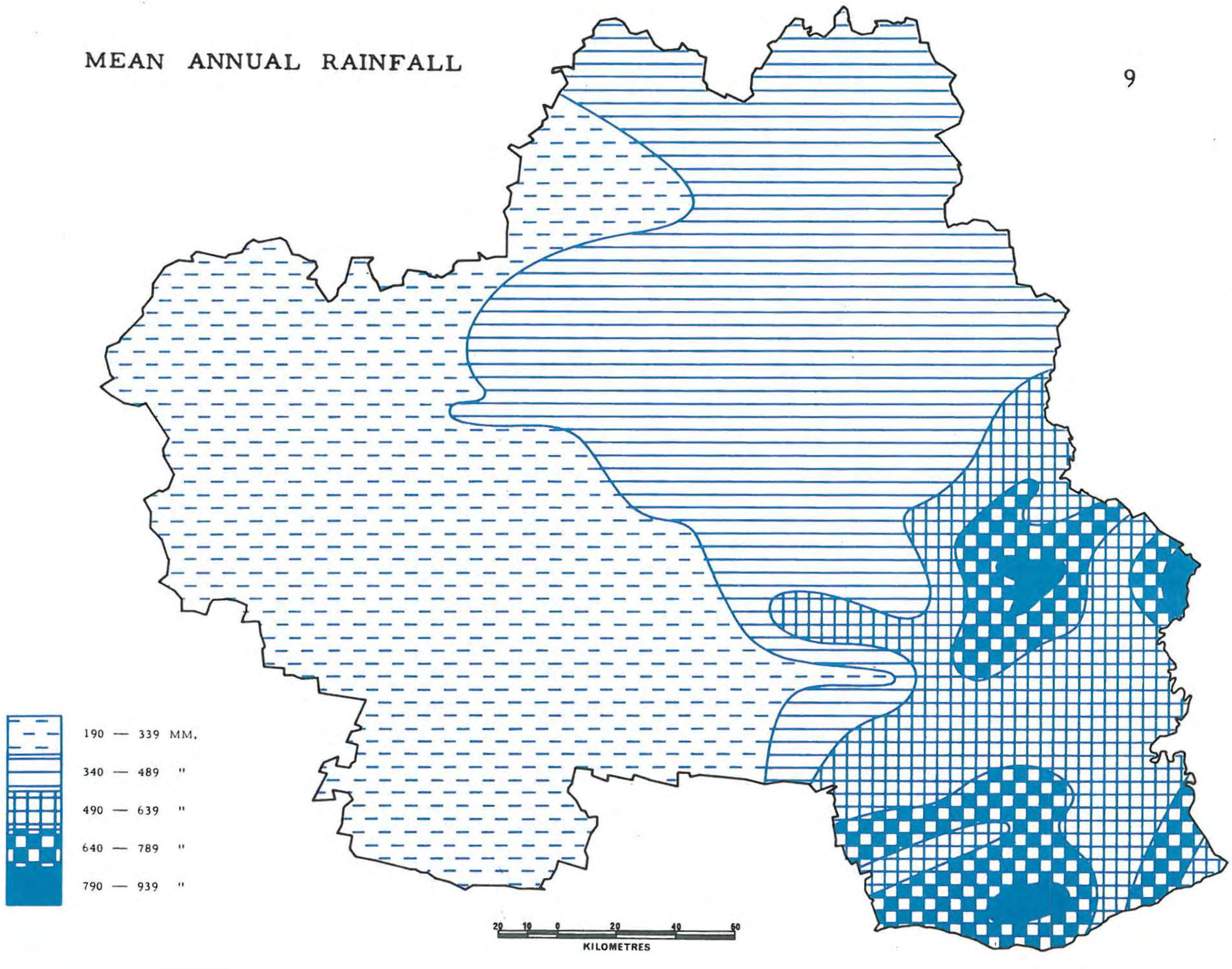
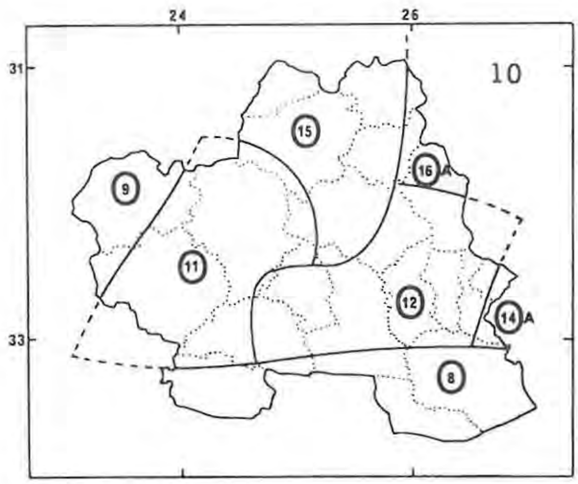
22. Jackson, S.P., "Climates of South Africa", South African Geographical Journal, Vol. 33, 1951, p. 24
23. Ibid., p. 26
24. Weerburo Publikasie: Klimaat van Suid-Afrika, "Streeksreënval", deel 5, W.B. 23, 1960, p. 1

MEAN ANNUAL RAINFALL





MAP 10: RAINFALL ZONES *

According to this zoning and these tables, the percentage value for the summer is as follows: (Oct. - March)

Zone	16A	75.1%
Zone	15	73.3%
Zone	14A	71.3%
Zone	12	68.9%
Zone	11	66.9%
Zone	9	66.2%
Zone	8	55.8%

There is thus a clear northward and eastward increase in the percentage summer precipitation.

ii. Mean Annual Rainfall and Rainfall Distribution

In South Africa precipitation occurs mainly as rain, both in frequency and in amount. The mean annual rainfall over the research area is shown in Map 9. ** As in the case for the rest of South Africa, the most important characteristics here are:

(i) the reasonably regular decrease over the interior plateau from east to west and

(ii) the very noticeable influence of orographic features.

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* Adapted from Weather Bureau Publication, Climate of South Africa, Regional Rainfall, W.B. 23

** Statistical data from which Map 9 was compiled was obtained from Weather Bureau Publication, Mean Monthly Rainfall, W.B. 29

MIDLANDS

(RAINFALL 1880–1958)

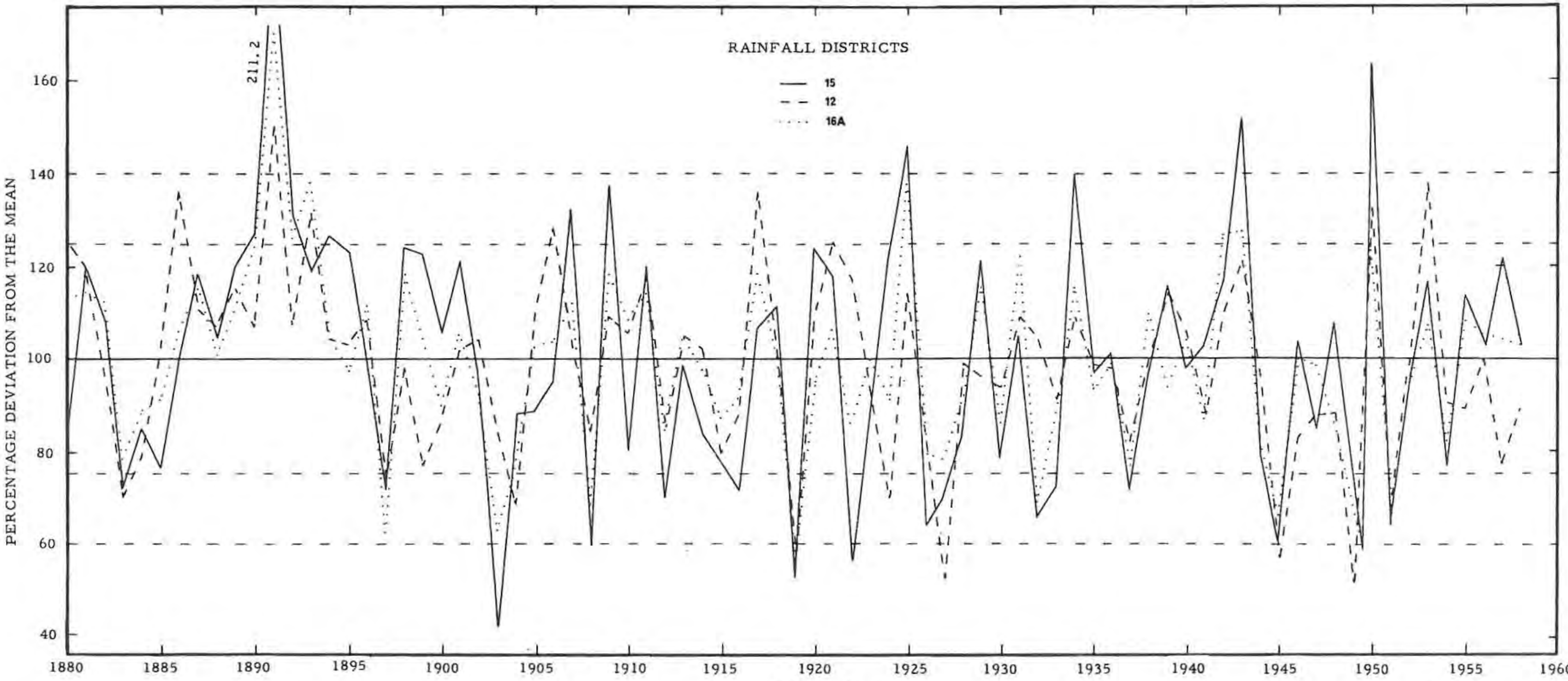

FIG. 2

KARROO

(RAINFALL 1880–1958)

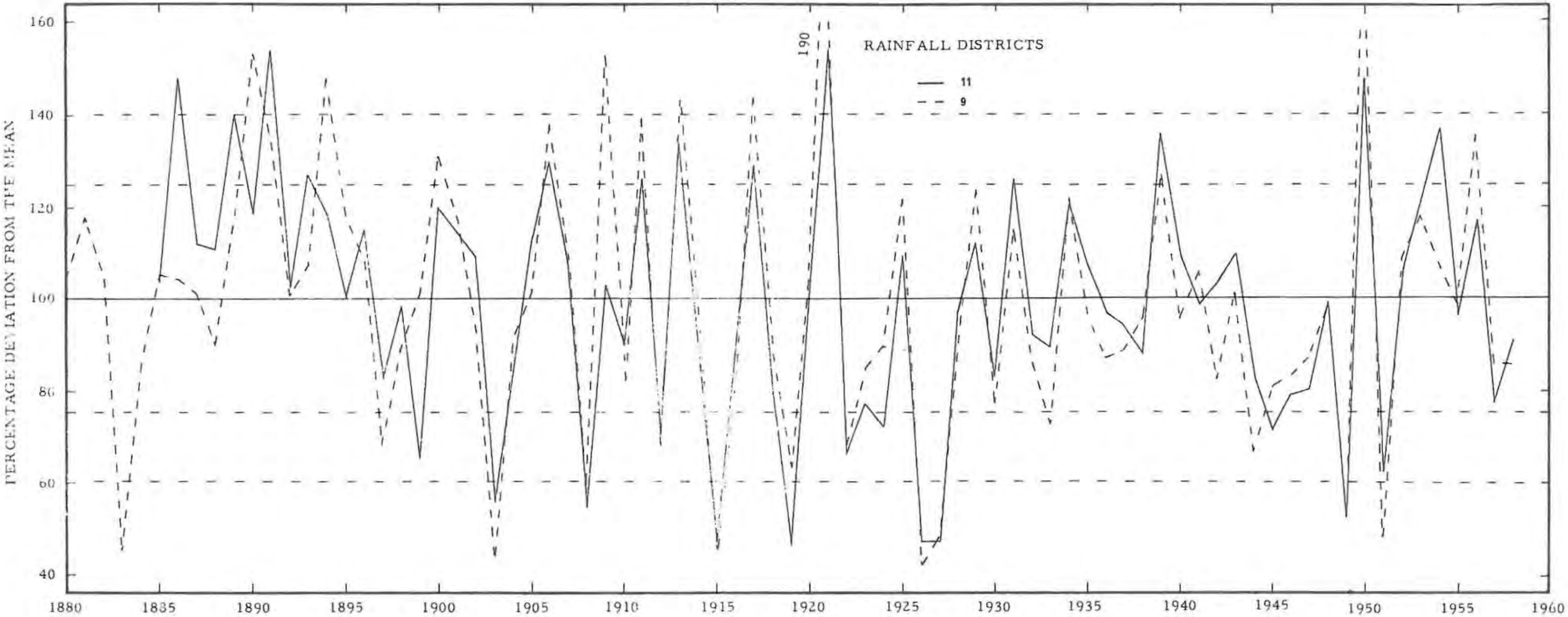

FIG. 2a

COASTAL PLATEAU

(RAINFALL 1880–1958)

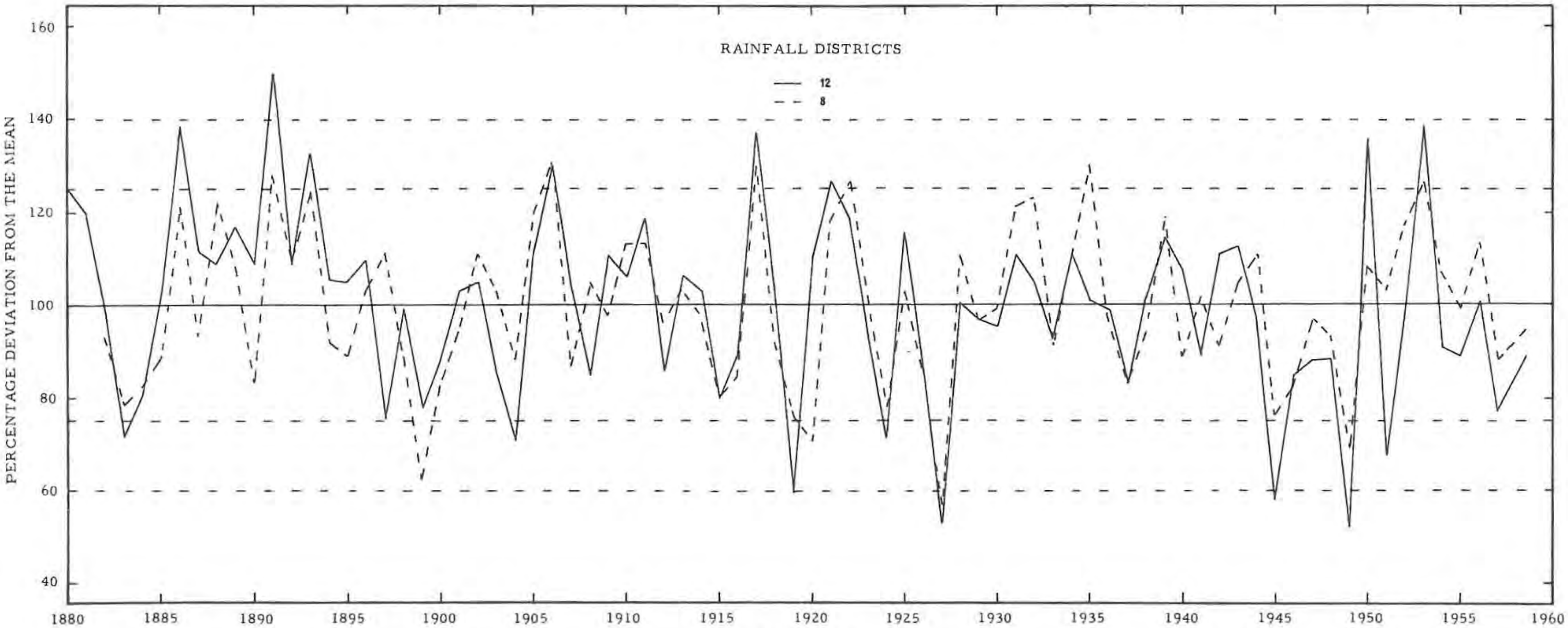

FIG. 2b

The highest rainfall is along the Second Escarpment, especially the rainfall concentration in the Winterberg area where the largest precipitations in the valleys of the Upper Koonap and Upper Kat River are experienced. Of further interest is the south-westerly decrease in the amount of rainfall from the Winterberg to the central and southern drainage area of the Great Fish River. Further towards the coast and along the lower reaches of the Great Fish River where it flows southeast there is again an increase in the annual precipitation.

The variation in the annual precipitation in the Midlands can be ascribed to the influence of orographic features. In this way the rainfall increases from 340 mm. in the central part of the Midlands to 500-625 mm. in the Bamboesberg and Suurberg. The lesser precipitation in the central depression can in the first instance be ascribed to the lower situation. Various factors such as distance from the sea, orientation in respect of rain-carrying wind and the nature of the rainfall (thunder-storm, cyclonic) probably determine the rainfall/height ratio. In the Southern Cape Province, around Graaff-Reinet, the increase in mean annual rainfall with height is 50. 8 mm. per 304. 8 metres.[25] A second factor is the rain shadow effect caused by the Second Escarpment. Although Cradock lies nearer the sea than Middelburg and Hofmeyr, the mean annual precipitation at the former is less than at the latter two observation stations. This tendency can be ascribed mainly to the difference in height above sea level, Cradock lying 391 metres lower than Middelburg and in the rain shadow influence of the Winterberg. In the eastern periphery of the Midlands, Steynsburg (1,448 metres) receives a rainfall of 409. 5 mm. per annum and Tarkastad (1,294 metres) gets 452. 2 mm. Here the

	PORT ALFRED	KLIPPLAAT	STEYTLERVILLE	GRAHAMSTOWN	JANSENVILLE	PEARSTON	SOMERSET EAST	BEDFORD	ADELAIDE	FORT BEAUFORT	ALICE	HOGSBACK	ABERDEEN	GRAAFF-REINET	CRADOCK	MURRAYSBURG	HOFMEYR	TARKASTAD	GROOTFONTEIN	STEYNSBURG
J	44.6	20.4	18.3	62.5	19.4	33.3	64.3	77.0	46.5	52.1	60.6	157.4	29.8	30.4	44.1	25.5	40.0	58.9	44.4	52.3
F	46.6	31.8	28.3	65.6	35.0	45.0	73.2	89.2	58.3	65.2	63.4	150.6	39.2	43.1	54.8	40.5	54.1	64.5	58.0	59.1
M	60.5	35.9	38.5	80.6	36.4	49.3	88.2	100.0	69.7	74.1	81.4	152.6	45.3	52.4	55.7	49.5	59.6	71.8	64.8	71.0
A	55.1	25.8	21.8	53.1	22.8	32.5	52.7	54.6	40.8	43.3	46.0	89.4	23.7	26.6	30.1	26.2	29.0	36.8	29.6	35.1
M	60.5	13.0	15.5	49.3	13.3	26.0	36.1	38.9	26.6	29.0	33.4	61.8	17.2	25.3	20.9	24.0	22.5	28.0	18.2	24.7
J	43.7	6.2	7.7	32.7	5.2	12.7	22.2	24.0	16.3	15.5	20.1	40.6	8.5	11.7	9.1	9.0	7.2	13.8	7.6	10.4
J	40.7	7.1	8.8	31.6	10.0	12.2	21.0	21.5	13.9	16.7	24.6	39.4	8.9	13.6	8.5	8.6	8.0	13.4	10.6	9.3
A	45.7	10.8	11.3	36.8	10.2	15.3	24.2	24.3	17.1	19.7	23.0	48.3	10.5	14.3	9.4	10.0	7.5	15.1	8.3	10.9
S	74.1	16.3	15.7	62.3	13.8	26.1	47.9	49.0	36.1	39.3	41.3	88.7	18.3	24.1	17.2	12.6	19.4	23.6	18.7	21.6
O	71.6	22.8	19.7	74.8	23.0	32.3	56.8	64.4	45.7	49.6	50.5	124.9	25.6	26.6	25.3	15.4	26.8	32.6	23.8	27.2
N	69.0	22.5	24.2	77.6	26.9	35.3	64.8	74.2	47.4	55.0	64.9	142.1	26.1	34.9	31.2	22.8	35.1	43.4	38.2	40.1
D	54.8	23.1	22.7	60.9	30.1	38.7	68.4	73.3	48.8	53.0	63.1	156.2	30.7	34.8	34.6	23.7	38.5	50.3	38.3	47.8
Year Jaar	666.9	235.7	232.5	687.8	246.1	358.7	619.8	690.4	467.2	512.6	572.3	1252.0	283.8	337.8	340.9	267.8	347.7	452.2	360.5	409.5

TABLE 6: MEAN ANNUAL AND MONTHLY RAINFALL IN MM*

* Adapted from Weather Bureau Publication, Climate of South Africa, Mean monthly rainfall, W. B. 29

25. Weather Bureau Publication, (W. B. 28), op. cit., p. 262

distance from the sea has a marked influence in the difference in rainfall, while the mountainous character of the environment is in both instances a common factor responsible for the higher rainfall.

The influence of the Second Escarpment on the distribution of the mean annual rainfall is very noticeable. The higher rainfall must be ascribed to the fact that the mountains extend at or near to right angles in respect of winds from anticyclones which in the summer months move eastwards out at sea, and drive cool Tropical air into the country with resulting orographic rains against the Second Escarpment. The rapid increase in an easterly direction here can in the first instance be ascribed to the normal distribution tendency over the whole of South Africa.

A second factor is the rain shadow effect of the Cape Fold Belt. Notwithstanding the fact that the Tandjiesberg attains an height of more than 1824 metres above sea level and that the Winterberg reaches an average height of 1520 metres, the mean annual precipitation is considerably higher in the latter mountain catchment area than in the former.[26] This difference can be ascribed largely to the presence of the Cape Fold Belt immediately south of the Tandjiesberg. To the east the southern Suurberg which is part of the Cape Fold Belt loses height rapidly, and disappears almost entirely to the south of the Winterberg.

The Cape Fold Belt does not only have an effect on the Second Escarpment, but is also directly responsible for the low rainfall in the east-flowing part of the Great Fish River. To the west the Cape Fold Belt is also partly responsible for the low rainfall over the eastern section of the Great Karroo that falls within the research area. The same distribution pattern as is found in the Midlands, viz. a gradual increase in the mean annual rainfall to the north and east, is also found here. The mean annual precipitation at Steytlerville (419 metres) is 232.5 mm., while it is 262.9 mm. and 315.8 mm. at Aberdeen and Graaff-Reinet respectively.

iii. Extremes of Annual Rainfall

As can be seen in Map 9, the highest rainfall occurs in the vicinity of the Winterberge and along the coast. At Hogsback, for example, the mean annual rainfall is ± 1,000 mm., and 934 and 650 mm. at the Alexandria Forest and Port Alfred respectively. The reason for this high-rainfall area near the coast is at present undetermined. The rainfall is lowest in the western and southwestern part of the research area, where the mean annual rainfall is about 250 mm. and less.

According to Fig. 2 * there is considerable range in the annual amount. This does not, however, indicate whether extreme values are likely to occur often or seldom. In order to obtain greater clarity in this regard, the annual regional values were divided into the groups 41-60% of the normal, 61-80%, 81-100% etc.

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* Statistical data from which Fig. 2 was compiled, was obtained from Weather Bureau Publication, District Rainfall, W.B. 23

26. Els, W.C., Die Evolusie van Grondgebruik in die Groot-Visriviervallei, Ongepubliseerde D. Litt. et Phil. Proefskrif, UNISA, 1965, p. 34

	below normal/ onder normaal			above normal/ bo normaal				
District Streek	% 41/60	% 61/80	% 81/100	% 101/120	% 121/160	% 141/180	% 161/180	% 181/-
16A	2	16	38	36	8	-	-	-
15	10	21	25	24	15	3	2	-
14A	-	13	38	44	3	2	-	-
12	7	8	41	36	8	-	-	-
11	12	17	28	24	16	3	-	-
9	12	10	40	17	12	5	2	1
8	2	8	43	36	11	-	-	-

TABLE 7: RELATIVE FREQUENCY (%) OF ANNUAL DISTRICT RAINFALL *

Take for example districts 16A, 14A, 12 and 8. According to Table 7, 74-82% of the annual rainfall falls within ± 20% of the normal. In other words, in about 7 to 8 cases out of ten these regions can on the whole expect an annual rainfall that is reasonably close to the normal. The position is totally different in districts 15, 11 and 9. Here only 49-57% of the annual rainfall is within 20% of the normal, while dry and very dry, and wet and very wet years often occur. This trend indicates an appreciable amount of change in the annual district rainfall and a great deal of fluctuation can be expected from year to year. Table 7 thus indicates that the changeability of the annual rainfall in the research area increases to the west and that the greater part of the Karroo and Midlands is subjected to periodic dry or wet deviations from the normal.

From the published rainfall data it emerges that in the present century, up to 1960, the years 1909, 1917, 1921, 1925, 1934, 1939, 1943, 1950 and 1955 were exceptionally wet years, when large parts of the country received 130% or more of the annual rainfall. In the same way 1903, 1908, 1912, 1922, 1926, 1927, 1932, 1945 and 1951 were exceptionally dry years, with only 70% or less of the normal rainfall. There is no regularity in the occurrence of dry and wet years. Mathematical analysis shows that no regular cycles exist and that there have been no significant changes in the rainfall regime since figures have been available. What does happen, however, is that while one part of the country is enjoying good rainfall, there is drought in other parts. The oft-bruited statement that South Africa is drying up, is not supported by facts and must therefore be rejected.[27]

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* Adapted from Weather Burea Publication, Climate of South Africa, General Survey, W.B. 28.

27. Weather Bureau Publication, (W.B. 28) op. cit., p. 267

In Fig 2 graphs of the progressive 12 monthly totals, expressed as a percentage of the annual mean, for 6 rainfall districts have been set out. The graphs for the rainfall districts that lie within a certain physiographic region or that overlap to a large extent, have been grouped together. These graphs serve to a certain extent to illustrate the recorded course of the rainfall history for the period 1880-1958, especially the cumulative effect of the periods of abnormal precipitation.

If one assumes that a condition of drought is reached as soon as the curves drop below the 75% mark as a result of sub-normal precipitation, it will continue until favourable precipitation causes the curves to rise above the 75% mark. In the same way it can be presumed that 60% of the annual mean indicates a severe drought. In Fig. 2, 75% and 60% have been marked by means of a horizontal dotted line, so that the relative intensity of the different droughts may easily be compared with one another. Rainfalls higher than 125% and 140% have similarly been marked so that exceptionally favourable periods may also be compared.

It is of importance to note that the climatic history of the few years immediately preceding the drought determines the severity thereof to a large extent. In the case of the Karroo and Midlands the drought of 1926-27 was of longer duration than that of 1933, but the latter inflicted far greater loss because it was preceded by <u>three</u> years of subnormal precipitation.

iv. Rainfall Types

As a result of the high temperature in summer, it seems that thunderstorms are the most common rainfall type over the northeastern part of the research area and that they attain their maximum frequency between January and March, when the average monthly temperature is at its highest.

From an analysis of the percentage of the total number of rain days per annum that are accompanied by thunderstorms and intensive atmospheric instability, it appears that the Midlands is dependent on thunderstorms for between 70 and 80% of its total rainfall; in the Second Escarpment area it decreases to between 25 and 30%, while the coastal belt receives rain as a result of thunderstorms for only 5 to 10% of the time.[28]

Especially along the Second Escarpment and to a lesser degree along the Great Escarpment, the rainfall type changes to relief rain. This orographic rain is found mainly during the summer months when cool Tropical maritime air penetrates the country from the south and southeast.

Along the coastal belt and to a lesser degree over the coastal plateau area, cyclonic rains occur during the winter months, and these come from the west.

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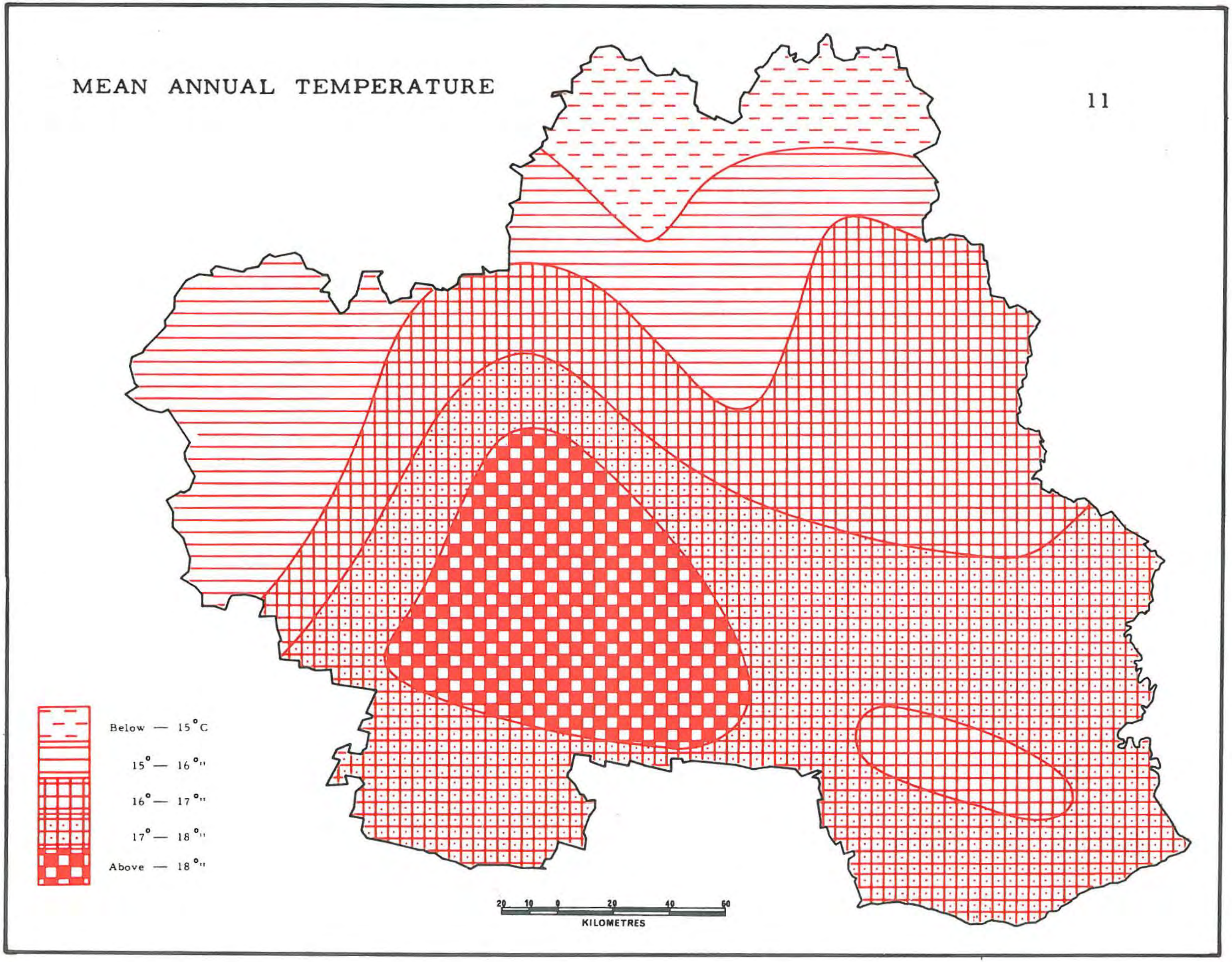
28. Els, W.C., op. cit., p. 41



MEAN ANNUAL TEMPERATURE
11
Below — 15°C
15° — 16° "
16° — 17° "
17° — 18° "
Above — 18° "
20 10 0 20 40 60
KILOMETRES

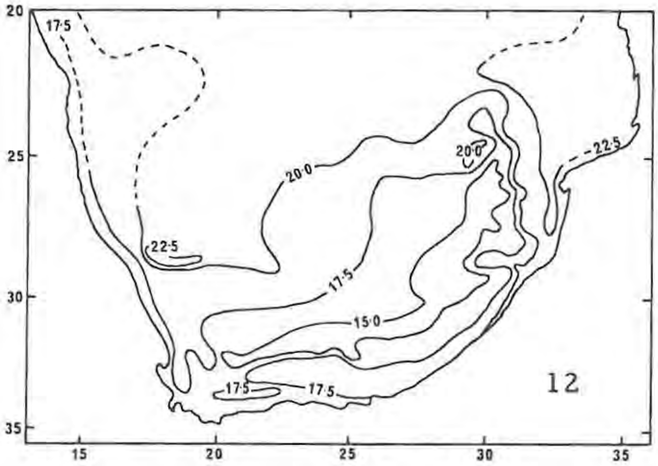
(g) Temperature

Besides rainfall, temperature is also an important meteorological element in the explanation of land use in the research area.

Temperature plays a determining role in land use, since the temperature requirements of plants cannot be supplied and met artificially on a large scale as is the case with vapour requirements, which may be supplemented by water conservation and irrigation. It is particularly the minimum temperature and the duration of the frost-free period that is decisive and about which nothing can be done. In this way, for instance, the northern distribution of fruit that is very susceptible to low temperatures is determined by the length of the frost-free period, rather than by rainfall or the amount of available irrigation water.[29]

i. Mean Annual Temperature

The 'true' mean temperature over South Africa is shown in Map 12. This map was drawn without taking height above sea level into consideration and may in no wise be used to deduce the temperature at a given point on the chart or to compare the temperatures at various given points on the chart with one another. A true representation of temperature along these lines would require a large-scale contour map, as well as a sound knowledge of how temperature drops as height increases in different topographical situations.



MAP 12: MEAN ANNUAL REAL ISOTHERMS

According to Map 12 it is clear that the isotherms more or less follow the contour lines. On the west coast the mean annual temperature is about 15 °C and on the east coast, at the same latitude, about 21°C. This difference of 6° can be attributed to the influence of the cold Benguela current along the west coast and the warm Mocambique and Agulhas currents along the east and south coasts. The effect of extensive low-lying areas is

29. Ibid., p. 49

particularly evident in the Great Karroo, where the temperature is higher than the surrounding higher country, and is to be attributed mainly to the cloudless days. This effect is equally applicable to smaller valleys that can, however, not be shown on a map of this size.

ii. Long-term Trends of Annual Mean Temperature

When the temperature trends are compared with the mean rainfall in the 8 rainfall zones of the research area, then the negative correlation between temperature and rainfall is apparent, namely, that during the periods when the mean rainfall is higher than the normal, then the mean temperature is inclined to be lower than normal in the corresponding period.

As in the case of rainfall, temperature also has a long-term fluctuation and has probably, by continued repetition, caused changes in the general circulation; periods of above-normal temperature have probably been brought about by continued anti-cyclonic conditions, encouraging subsidence, clear sky and optimum sunshine, while subnormal temperatures are to be attributed to more continued cyclonic activity, together with overcast skies and little sunshine.[30]

iii. The Annual March of Temperature

In order to obtain a general view of the annual temperature change over the research area, diagrams showing the annual march monthly and diurnal change and annual mean of temperatures at different observation stations have been drawn. (See Fig. 3). The mean absolute maximum and minimum temperatures have also been indicated on the diagrams, seeing that they can be used as additional information in connection with frost periods. The minimum and maximum temperatures that have till now occurred in the research area, give an indication when they are analysed, of the extremes that can be expected, as well as the severity thereof.

These temperature stations have been chosen in such a way that they are representative of the four main physiographic regions, viz., the Midlands (Grootfontein and Cradock), the Coastal Plateau Area (Somerset East and Grahamstown), the Karroo (Graaff-Reinet and Jansenville) and the Coastal Belt (Port Alfred).

The most important characteristic of the regular (periodic) march of temperature in the research area can be summed up as follows:

(i) At the observation stations along the coast, the minimum temperatures are inclined to be stable and not subject to great fluctuation, while there are exceptional values that occur for the maximum temperatures. This trend is in agreement with the fact that the coastal belt is occasionally subject to bergwinds. Over the interior, the maximum temperatures show a stable trend, while the minimum temperatures are subject to great extremes, because the interior is occasionally under the influence of sub-antarctic air.

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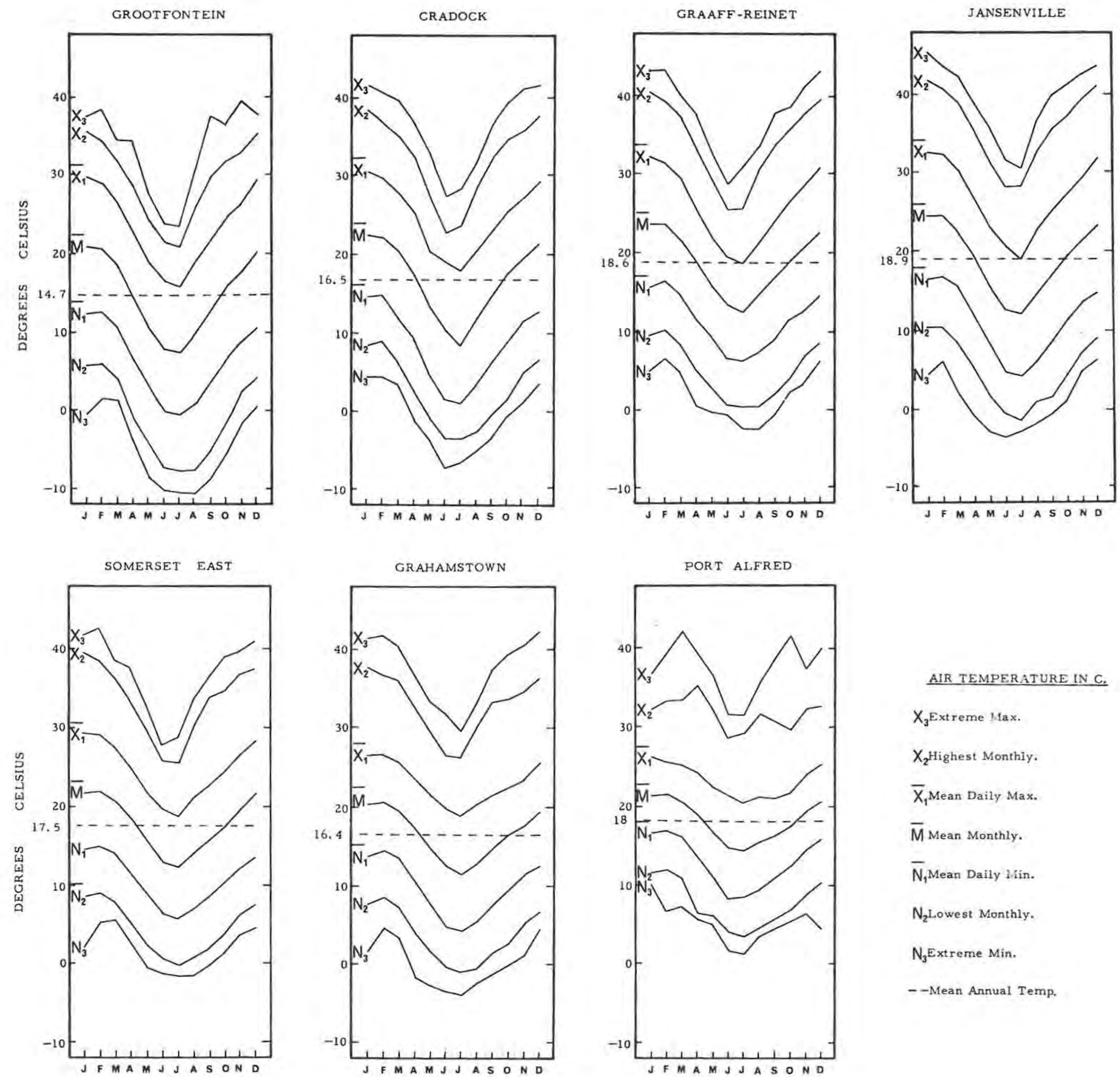
30. Weather Bureau Publication, (W. B. 28), op. cit., p. 83


GROOTFONTEIN
CRADOCK
GRAAFF-REINET
JANSENVILLE
SOMERSET EAST
GRAHAMSTOWN
PORT ALFRED
DEGREES CELSIUS
14.7
16.5
18.6
18.9
17.5
16.4
18
J F M A M J J A S O N D
AIR TEMPERATURE IN C.
X3 Extreme Max.
X2 Highest Monthly.
X1 Mean Daily Max.
M Mean Monthly.
N1 Mean Daily Min.
N2 Lowest Monthly.
N3 Extreme Min.
--Mean Annual Temp.

	J	F	M	A	M	J	J	A	S	O	N	D	Year Jaar	Range Speling
PORT ALFRED	21.3	21.4	20.6	18.9	16.6	14.7	14.4	15.3	16.0	17.2	19.2	20.6	18.0	10.6
GREAT FISH POINT	20.7	20.9	20.1	18.7	17.5	15.7	14.9	15.7	16.3	17.2	18.5	19.9	18.0	7.8
GRAHAMSTOWN	20.2	20.6	19.7	17.1	14.7	12.4	11.6	12.9	14.6	16.1	17.4	19.2	16.4	13.4
JANSENVILLE	24.7	24.7	22.9	19.5	15.6	12.8	12.1	14.4	17.0	19.3	21.5	23.3	18.9	15.9
SOMERSET EAST	21.9	22.0	20.7	18.2	15.4	12.9	12.3	14.0	15.6	17.3	19.1	20.9	17.5	13.9
FORT BEAUFORT	22.3	22.3	20.9	18.4	14.7	12.6	12.2	14.1	15.6	17.6	19.7	21.4	17.7	15.3
GRAAFF-REINET	23.9	23.9	21.9	18.9	15.7	13.1	12.5	14.3	16.5	18.7	20.8	22.7	18.6	14.6
CRADOCK	22.3	22.1	20.4	17.1	13.1	10.1	9.4	11.9	14.5	17.3	19.3	21.1	16.5	16.3
MURRAYSBURG	22.0	21.7	19.3	15.4	10.7	8.1	7.9	9.7	12.2	16.3	18.2	21.2	15.2	15.9
HOFMEYR	20.7	30.7	19.8	17.3	14.6	12.7	12.2	14.1	15.6	17.0	18.1	19.8	16.9	12.9
MIDDELBURG	20.9	20.7	18.5	14.6	10.9	7.9	7.3	9.7	12.5	15.4	17.6	20.1	14.7	16.9
STEYNSBURG	21.2	20.5	18.2	13.8	9.7	7.2	6.8	9.2	12.3	15.9	18.1	20.5	14.4	15.2
BEDFORD	21.5	21.5	19.9	17.6	14.4	12.6	11.7	13.3	14.7	16.4	18.5	20.6	16.9	13.6
BATHURST	21.5	21.7	20.6	19.1	16.9	15.4	15.1	15.8	16.1	16.8	18.5	20.1	18.1	9.9
LAKE MENTZ	24.5	24.9	23.0	19.9	15.1	11.5	11.5	14.1	16.5	19.3	21.8	23.9	18.9	15.3

TABLE 8: MEAN MONTHLY AND ANNUAL TEMPERATURE IN °C

(ii) From Table 8 it would seem that the temperature range over the Midlands and Karroo is the greatest and that it decreases towards the coast. From a comparison of the diurnal maximum temperature for the year in the four physiographic regions, there is an increase from the coast (Great Fish Point 21.9 °C) to the coastal plateau area (Grahamstown 23.1 °C and Somerset East 24.5 °C) and the Karroo (Graaff-Reinet 25.9 °C and Jansenville 26.9 °C). Towards the Midlands (Cradock 24.7 °C and Grootfontein 23.1 °C) there is a slight decrease that can be attributed mainly to the greater height (Cradock 872 metres and Grootfontein 1263 metres). The average decrease of the mean temperature in the southern Cape Province with increase in height is .55 °C for 100 metres.[31] The mean diurnal minimum temperature for the year shows a similar decrease from the coast (Great Fish Point 14.1 °C) to the coastal plateau area (Grahamstown 9.7 °C and Somerset East 10.6 °C), Karroo (Graaff-Reinet 11.3 °C and Jansenville 11 °C) and Midlands (Cradock 8.4 °C and Grootfontein 6.2 °C). According to Table 8 it is further clear that the diurnal mean temperature for the year follows the same pattern of decrease.

(iii) The diurnal temperature range is to a large extent determined by the quantity of clouds. In the summer rainfall region there is an increase in the daily range from summer to winter, and in the winter rainfall region the range is the greatest during summer and the smallest during winter. In the southern coastal belt and Great Karroo the range, however, shows little change throughout the year. Port Alfred shows a slight maximum shift towards the winter months which can be attributed to a greater occurrence of cloudiness during the summer months.

31. Ibid., p. 98

FIG. 4 CLIMOGRAPHS

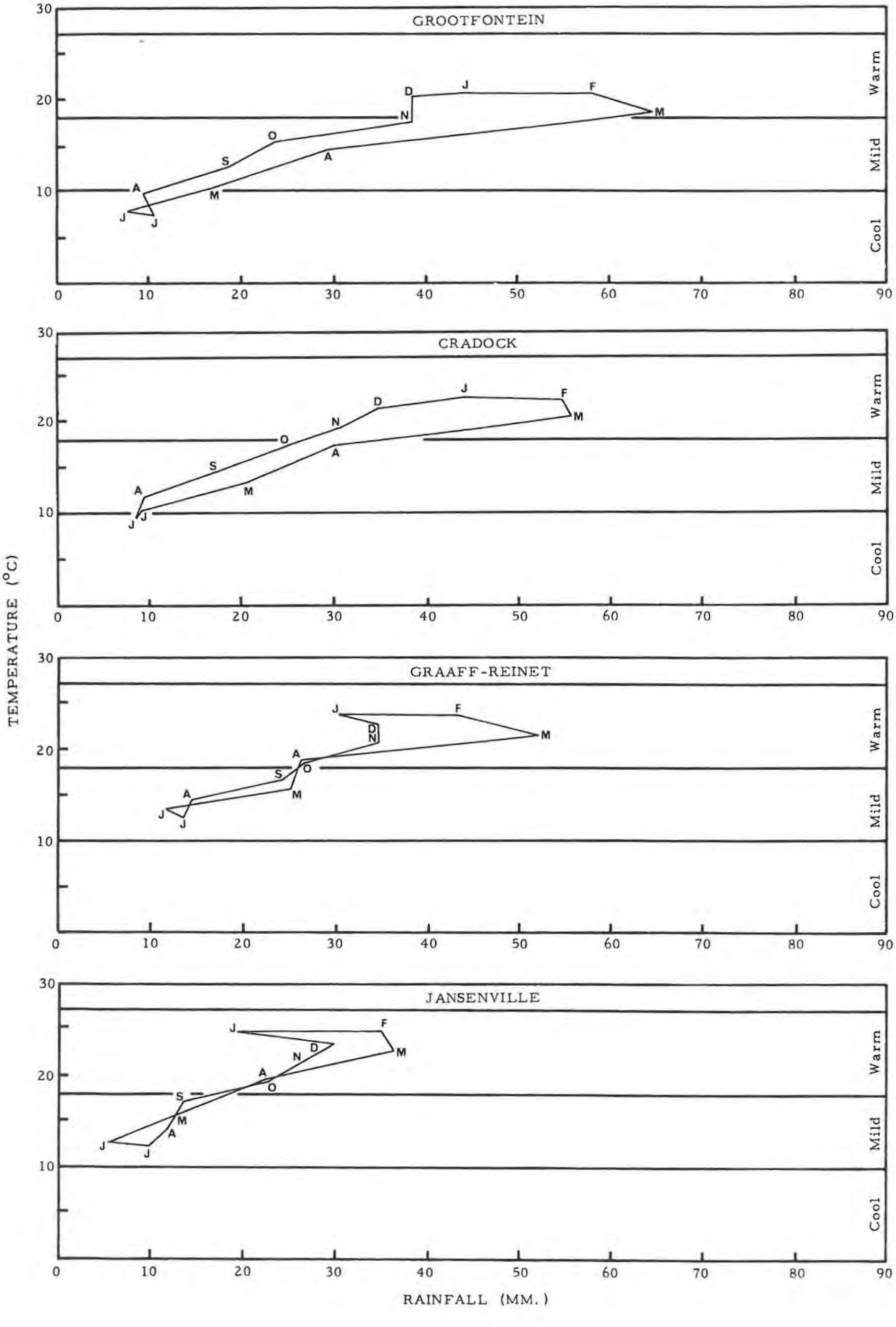
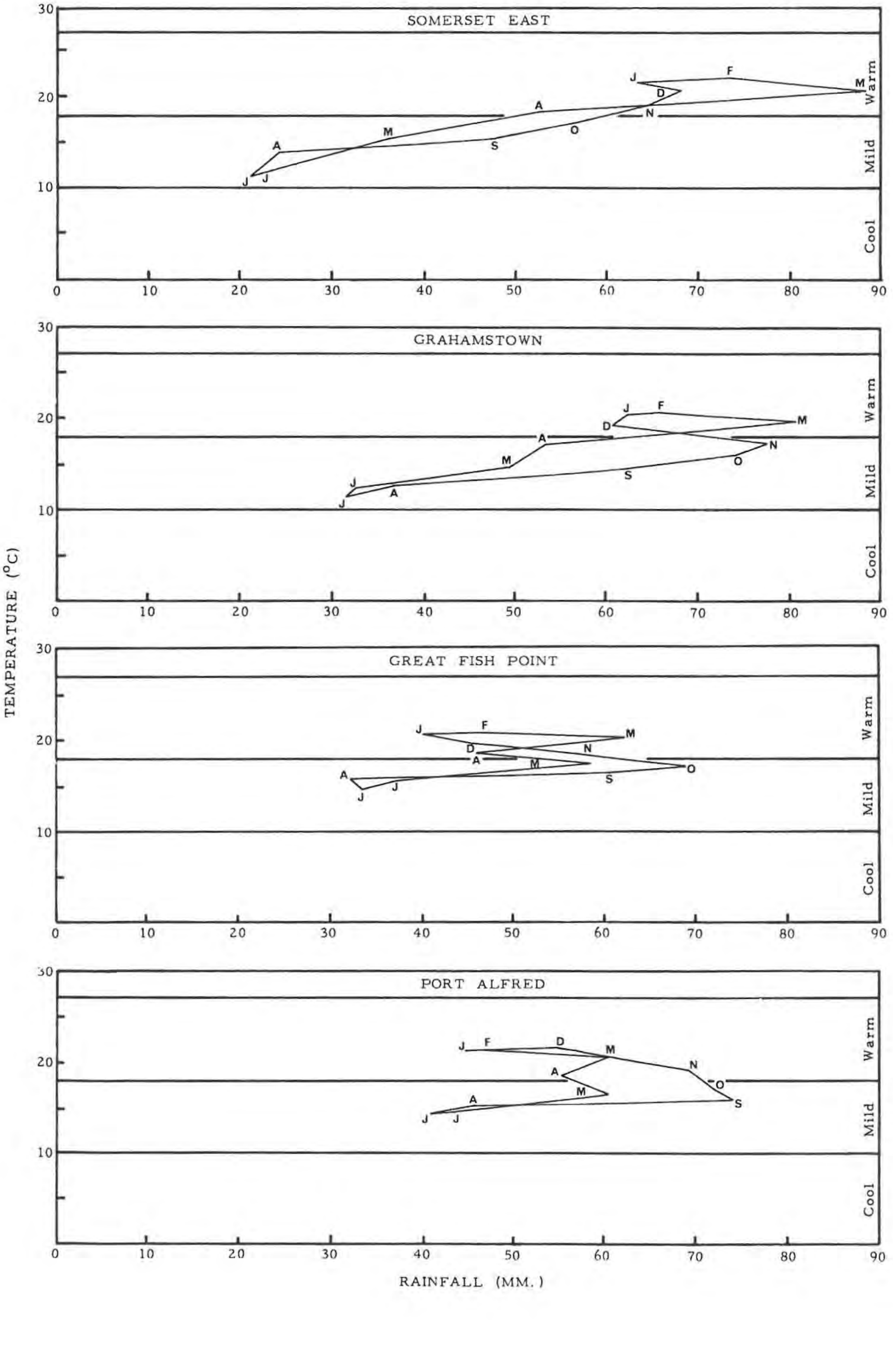


FIG. 4a CLIMOGRAPHS



(iv) The curves showing the annual variation of the mean temperatures are almost perfect sine curves in the Karroo and Midlands, with a maximum in January and a minimum in July, mainly as a result of the many clear or slightly overcase conditions that occur throughout the year. Along the coast the annual march of mean temperature is slowed down as a result of the influence of the sea, and the maximum falls in February and the minimum in late July or August. According to Table 8 it is clear that this influence is not only restricted to the regions along the coast, but also occur as far inland as the Bathurst and Grahamstown region.

iv. Climograph

By making use of Climographs (See Fig. 4) two climatic elements, in this case temperature and rainfall, can be compared with each other by tabulating them simultaneously. The mean temperature is shown on the vertical scale, while the mean monthly rainfall is shown on the horizontal scale. "The climatogram has the advantage of continuity, and the shape and position of the resultant graph provides an index of the general climatic character at that place."[33] The expression was first used by Griffith Taylor, while the temperature limits for the warm, moderate and cool zones are based on Thornwaite's formula.

In the compilation of the climatograms, two observation stations were selected from each of the four physiographic regions viz., the coastal areas, coastal plateau area, Karroo and Midlands. There is great correspondence between the observation stations for each of these physiographic regions as regards the shape and position of the polygons. The coastal stations both show a relatively small temperature and rainfall range. The highest rainfall is experienced between September and October, and Great Fish Point shows a double maximum, during March and April. The position of all the temperature and rainfall intercepts is in the vicinity of the boundary between the moderate and warm zones, and the climate can be seen as moderate to warm. On the coastal plateau, Somerset East displays more markedly continental characteristics than Grahamstown. While the winter temperatures are more or less the same, Somerset East is inclined to a greater summer maximum. Both stations experience their maximum precipitation during March. As in the case of Great Fish Point, Grahamstown exhibits a double maximum.

Over the Karroo, true continental conditions predominate, with a great variation between winter and summer temperatures. The winter and summer temperatures are inclined to be higher over the Karroo. At Grootfontein, three months of the year fall within the cool zone.

(h) Frost

Next to rainfall and temperature,frost is also an important determining factor, especially in the production of summer grains and plants sensitive to frost. There must, also be a further distinction between light and heavy frost, as well as between the entry and exit dates of frost,

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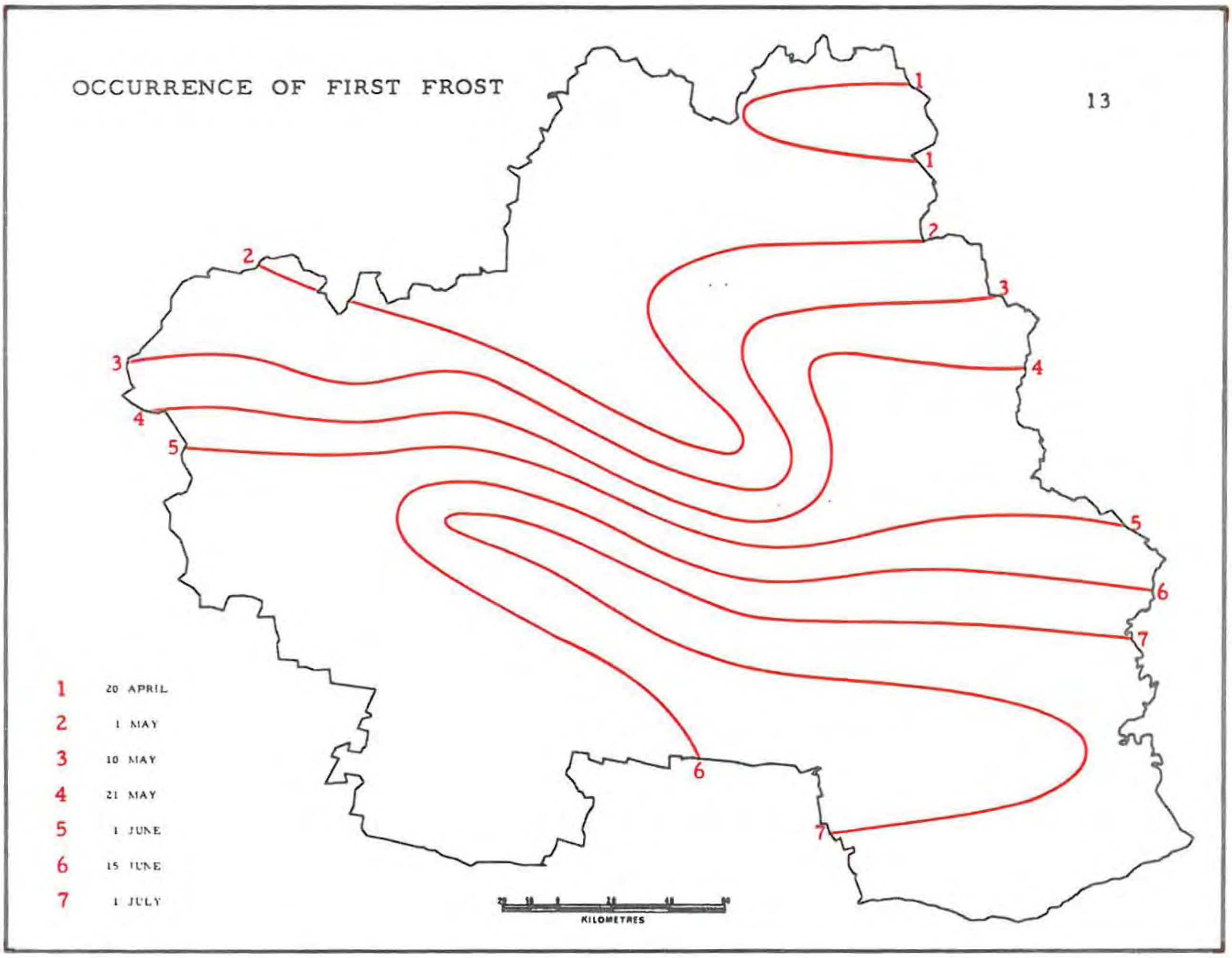
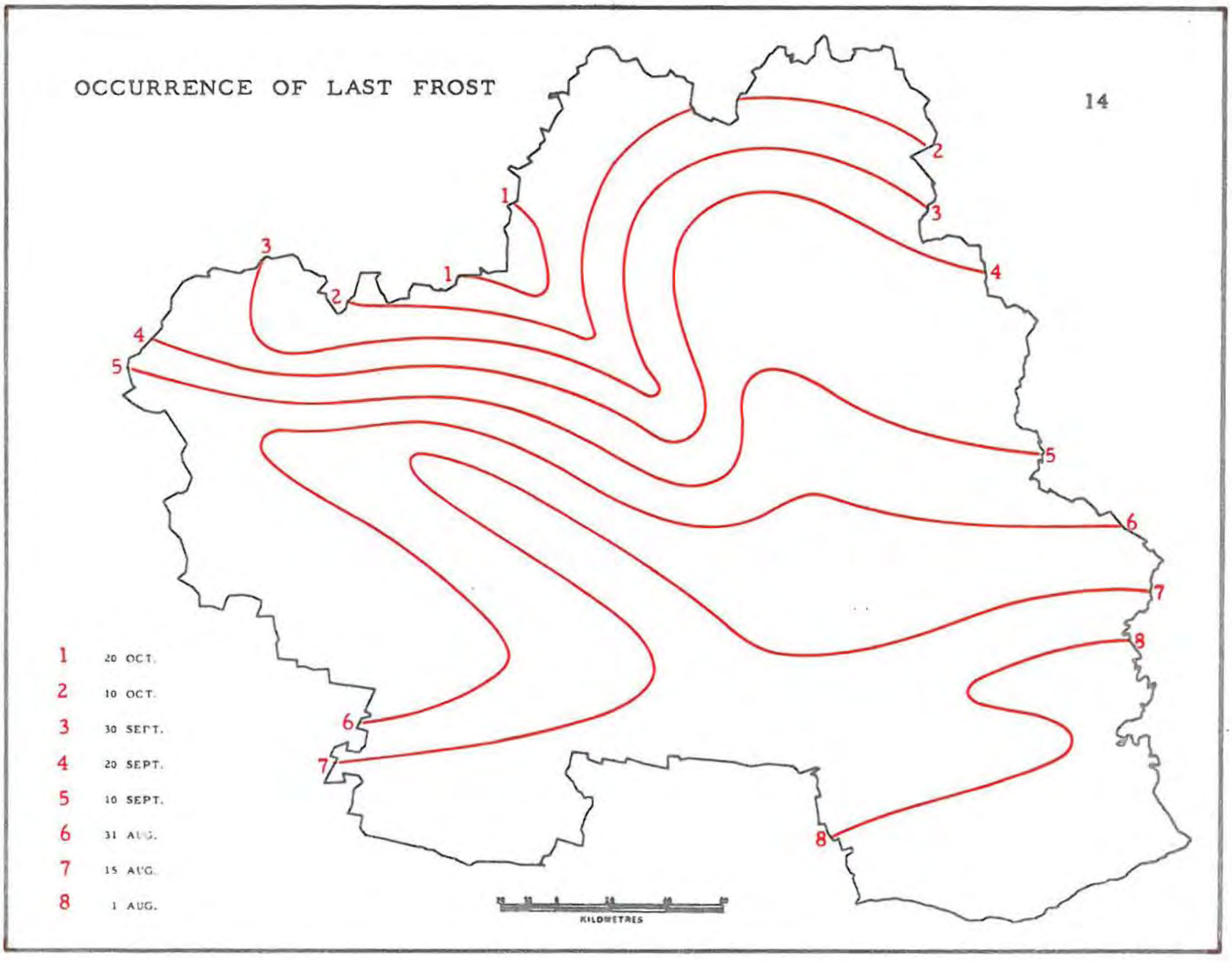
32. Ibid., p. 92
33. Monkhouse, F. J., and Wilkinson, H. R., Maps and Diagrams, Methuen and Co. Ltd., London, 1963, p. 197


OCCURRENCE OF FIRST FROST
13
1 20 APRIL
2 1 MAY
3 10 MAY
4 21 MAY
5 1 JUNE
6 15 JUNE
7 1 JULY
KILOMETRES


OCCURRENCE OF LAST FROST
14
1 20 OCT.
2 10 OCT.
3 30 SEPT.
4 20 SEPT.
5 10 SEPT.
6 31 AUG.
7 15 AUG.
8 1 AUG.
KILOMETRES

seeing that it affects the type of land use. This influence is not only restricted to agriculture, but also has much to do with the natural foliage, and the occurrence of frost can damage the spring growth.

Frost, particularly in the form of hoar frost, is a common phenomenon in South Africa and is mainly the result of intensive nocturnal radiation of heat. The conditions most conducive to frost are:

i. Reasonably dry atmosphere and clear sky. During winter this condition is almost always found over the interior, but seldom along the coastal belt.

ii. A reasonably non-conducting layer (grass covering, loosely tilled soil etc.) at the surface that obstructs conduction from the deeper layers of the ground. This condition depends completely on the nature of the surface in different environs.

iii. The absence of wind that is favourable to the stratification of the air and a strong temperature inversion. Local topography plays an important role here, and also determines the exposure to the sun during the day, which causes the northern slopes (in South Africa) to receive more heat than the slopes that face south; the former are thus less subject to frost.

The regularity and severity of frost are inter alia affected and determined by the consecutive recurrence of frost, topography, texture and colour of the soil and height and density of the undergrowth.

The result of all this is that the regional distribution of frost appears very spotty, and that the regional illustration of the first and last dates on which frost occurs only gives a very generalized picture of the true state of affairs and cannot be adequately illustrated on a map.

In the compilation of Maps 13 and 14 the requirement for frost is a minimum temperature below 0 °C, taken where the thermometer is exposed at the height of 1.2 metres in a Stevenson Screen. The mean date for the occurrence of the first and last frost is determined by finding the $\bar{X}$ of the relevant dates for each station.[34]

In order to determine the severity of frost, there is also the additional problem that the decrease or increase in temperature usually exhibits the greatest amount of range in the first foot (.3 metres) of the atmosphere and that temperatures in this zone can show a discrepancy of up to 6.3 °C from those taken in the shelter. Whatever the case may be, it is necessary to accept one or other criterion, and it has been calculated that there is a mean difference of 2.6 °C between temperatures inside and outside the screen in winter, although it varies with the nature of the surface and the presence of clouds (or very humid air) or wind. In general, damage to fibres of growing plants does not occur before the air temperature at that plant height has dropped to the freezing point of water (°C). For the sake of comparison, a screen temperature of –2.6 °C and less is taken as a sign of sharp and killing frost. If the air is dry at the same time, and the

34. Weather Bureau Publication, (W.B. 28), op. cit., p. 134

temperature drops below freezing without reaching the dew point, no ice crystals are formed, but it is extremely dangerous for vegetation in particular and is known as 'black frost'. By watering plants in the afternoon, the water content of the lowest atmospheric strata is increased and is at times an effective method of lessening the chances of frost damage. A screen temperature of 0 °C can be taken as an indication of harmful frost on the ground and as high as leaves, blossoms and fruit of trees.[35] Light (or ground) frost can easily occur, even if the screen minimum temperature is slightly over 0 °C. If 3 °C were to be taken as the criterion for light frost, then the mean dates for first and last occurrence of frost would be about 18 days earlier and later than is shown in Maps 13 and 14, and the mean duration of the period of light frost would be about 35 days longer.

By reading the difference between the two sets of date lines in Maps 13 and 14, the mean duration of the frost period may be ascertained. As may be expected, the frost period lasts longer on the higher-lying Midlands than in the relatively lower-lying parts nearer the sea. In general the frost appears first and last of all in the higher-lying valleys at the edge of the Great Escarpment. Over the northern part of the Midlands the frost period is ± 174 days and decreases to the south until it is ± 112 days in the vicinity of Cradock. The most noticeable characteristic of these maps is the rapid increase in the length of the frost period over the central part of the Midlands, and this is attributable to the increase in height above sea level of the Tandjiesberg-Winterberg range. On the Second Escarpment the duration of the frost period is 61-92 days and over the coastal plateau, about 30 days.

3. Relationship Between Climate and Land Use

"It is well known that the farming potentialities of any area tend to be determined not so much by the favourable as by the adverse or restrictive, qualities of the environment. That is to say, success in farming is mainly a function of the least risk. Hence the need for particular study of the limitations of the climatic environment."[36] Within the research area it is particularly rainfall, temperature, evaporation and the occurrence and duration of frost period that may be considered particular climatic controls of land use patterns. "Generally speaking, livestock have a wider range of climatic tolerance than crop plants,"[37] and one finds that the distribution of sheep and cattle within the research area is not directly affected by climate to any large degree, but indirectly - as will be seen later.

Out of a total of 72,462 square kilometres, only 1.96% is under cultivation of which ± 46% falls within the boundaries of six magisterial districts, viz. Alexandria, Albany, Victoria East, Stockenström, Fort Beaufort and Bathurst. The greater part of the remaining 54% occurs as irrigation lands on the Great Fish and Sundays Rivers.

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35. Whitmore, J.S., "Frost" Farming in South Africa, April, 1949, p. 226
36. Whitmore, J.S., "Influence of climate factors in the agricultural development of South Africa", South African Geographical Journal, Vol. 37, May, 1957, p. 7
37. Ibid., p. 19

(a) Cultivated Land

i. Precipitation

In the Midlands and central and western surrounding areas of the Second Escarpment, from 66% to 73% of the total annual mean precipitation is recorded during the summer months. The amount that occurs during the sowing season (Oct-Dec) is, however, too small for the cultivation of summer plants. The monthly distribution is also poor because the summer rains occur mainly in the form of downpours. The amount of precipitation during March, April and May is reasonably sufficient for the sowing of winter crops, but after that the amount of precipitation is not enough for a certain harvest. The periodic occurrence of snow makes the winter precipitation more effective. Although the climate of the Midlands is not advantageous for crops and it is mainly a stock-farming region, agriculture, especially the cultivation of winter wheat as grazing, plays quite a significant role, even though it covers only a small part of the surface. The wheat is mainly cultivated under the "saaidam"* system. Besides wheat, mealies and lucerne are grown for the farmers' own use, as will be seen later in this study.

In the Karroo the precipitation is too low in winter and summer for dry land cultivation. Where irrigation water is available, some wheat and other crops are grown. It is very evident that crop-farming plays a very minor role in this region. While the total area of the land under cultivation, expressed as a percentage of the total area per magisterial district, is on the average 1.61% in the Midlands, this decreases to only .68% in the Karroo. Once again the correlation between these percentages and Map 9 showing the mean annual rainfall, is remarkable.

As indicated on the land use map, the greatest concentration of agriculture is in the south-eastern corner of the research area and is mainly as a result of the higher rainfall. The influence of the dry Great Fish River Valley on the general pattern of land use is also clearly indicated. In the vicinity of the Suurberg and to the south thereof, the distribution of rainfall is such that both summer and winter crops can be grown, should the soil and other factors be favourable. Crops thus play an important part in the system of farming here, even though the greater part of the farming surface area is used for grazing. The region along the coast, mainly the magisterial districts of Alexandria and Bathurst, forms part of the agro-economic region that produces nearly all the chicory of the Republic, while it is also the most important pineapple region in the country. Besides these two products, mealies, vegetables and fruit also contribute to the steady income.

ii. Frost

Over the coastal plateau the winters are moderate and frost may occur from 25th May to 20th August. In the central parts of the Midlands, heavy frost occurs from the last week in April and is a nightly occurrence till the middle of September.

Almost without exception citrus requires relatively warm winter temperatures, and the production is consequently concentrated in parts

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* Flood irrigation without storage

with moderate winters and short frost periods.[37] The most important citrus-producing magisterial districts are thus Albany, Bathurst, Stockenström, Fort Beaufort and Victoria East. The climatic requirements for deciduous fruit are exactly the opposite. Lack of sufficient winter cold during the rest period gives rise to a condition known as delayed foliation that has an adverse effect on the fruit crop. With sufficient water supplies and thorough studies, similar to the study by De Villiers[38] of the required winter cold for various varieties of fruit in the Western Province, a great deal of the Midlands may be seen to be fit for the cultivation of deciduous fruit.

iii. Evaporation

The role of transpiration as an important growth process is of a complex nature. It is, however, enough to state that the active water use of a plant shows a wide variation and that probably only 1 or 2 per cent of all the water that is transpired by a plant in the course of a season is retained in the plant fibres. In the absence of good crop management, great quantities of water can be lost by evaporation and transpiration, while the economic yield is only minimal. "But the more exactly the supply of water can be synchronised with the requirements of the plant at its various stages of growth, the greater becomes the return per unit of water used. This is a fundamental precept in the efficient and economic utilisation of the climatic resources."[39] While it is impossible to regulate the growth rate of a plant with certainty, it is possible, by means of a judicious selection of planting dates and suitable varieties, to put foliage in line with the general climatological rhythm of a particular region or area. In the dry parts where the practice of agriculture is dependent on irrigation water, the problem can be solved by the judicious use of water. During summer, up to 50% of the precipitation on a mealie-land can be lost as a result of evaporation. Correct cultivation of the land increases the maximum penetration of water, and by placing the fertilizing materials deeper down, the volume of soil from which the plant may draw its food and water supplies is increased.[40]

(b) Stock Rearing

At present, stock-farming, especially extensive sheep-farming, is the most important economic activity especially in the Midlands and Karroo region. The greater part of 14 of the 21 magisterial districts form part of the 3 agro-economic regions of extensive sheep-grazing, viz., the Mountain Karroo, Southern Karroo and Broken Karroo, that overlap the Midlands and Karroo to a degree. The Broken Karroo region, beginning as a narrow strip all along the Great Fish River and stretching eastwards to the coast, is not exclusively suitable for small stock farming, but cattle farming becomes more important to the east where the rainfall is higher

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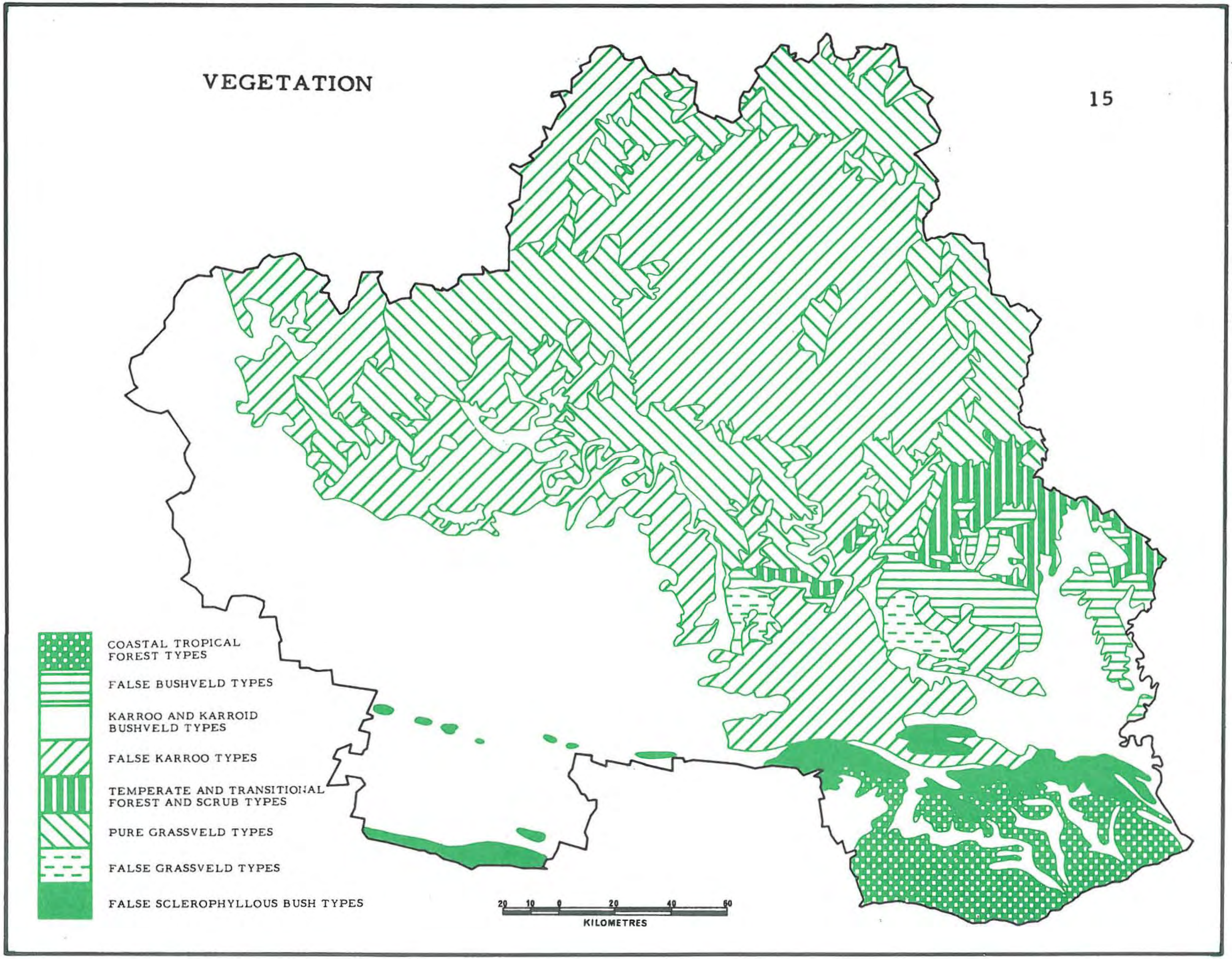
37. Ibid., p. 19
38. De Villiers, G. DB., "Winter Temperatures and Fruit Yield", Farming in South Africa, Vol. 22, No. 257, 1947, pp. 638-644
39. Whitmore, J. S., op. cit., p. 22
40. Ibid., p. 23

and there is more grass.[41] As a result of higher rainfall and better grazing, most of the cattle are found to the east of the 490 mm. isohyet.

It is noticeable that there is a correlation between the westward decrease in the mean annual rainfall and cattle farming. Between the 340 and 490 mm. isohyets, i. e. the Midlands, many cattle are found and contribute 10% of the total income as opposed to 80% from sheep-farming.[42] To the west of the 340 mm. isohyet, cattle farming is responsible for only 2. 5% of the total income, while small stock are responsible for 94%.[43]

To the east of the 490 mm. isohyet farming is mixed with the production of several commodities, but cattle and sheep are the two most important sources of income. Along the coast dairy farming, especially the delivery of fresh milk, is a very important constituent of cattle farming.

41. Agro-Economic Survey of the Union, Vol. VII, No. 43, 1955, p. 24
42. Ibid., p. 88
43. Ibid., p. 204



VEGETATION
15
COASTAL TROPICAL FOREST TYPES
FALSE BUSHVELD TYPES
KARROO AND KARROID BUSHVELD TYPES
FALSE KARROO TYPES
TEMPERATE AND TRANSITIONAL FOREST AND SCRUB TYPES
PURE GRASSVELD TYPES
FALSE GRASSVELD TYPES
FALSE SCLEROPHYLLOUS BUSH TYPES
20 10 0 20 40 60
KILOMETRES

E. VEGETATION

The natural flora is the result of thousands of years of interaction between the plants, climate as the most important factor and a host of other factors such as topography, types of soil, animal life, etc. The distribution of the vegetation as it is seen today is primarily the result of the migration of vegetation species along various routes as determined by local topography and rainfall distribution, and secondarily the result of the activities of the Bantu and Europeans during the last 300 years and in particular the last century. Because the natural vegetation is inclined to change according to the way that it is treated, directly and indirectly by man there is in South Africa little or no vegetation that has been preserved in its original form.

Map 15 shows the eight main veld Types in the research area, which are the following types:

1. Tropical Coastal Forest
2. False Bushveld
3. Karroo and Karroid
4. False Karroo
5. Temperate and Transitional Forest and Scrub
6. Pure Grassveld
7. False Grassveld
8. False Sclerophyllous Bush

The two dominant ecological regions are, however, No. 3 the Karroo and Karroid Type and No. 4 the False Karroo Type which together constitute the greater part of 14 of the 21 magisterial districts.

In order to avoid unnecessary repetition, the vegetation is discussed according to Types, with special reference to district distribution, instead of according to physiographical regions.

1. Coastal Tropical Forest Types

(a) Alexandria Forest Sub-Type

This forest Sub-Type is found in the magisterial districts of Bathurst, Alexandria and southern Albany, as a south-western extension of the tropical forests along the coast. The greatest extent and best development is, however, found in Alexandria, where the forest is short and very dense. The forest also consists of a relatively large variety of species.

Along the coast the landscape is gently undulating, except in the eastern part of Alexandria where the valleys are deep and rocky. Here the transition from the Alexandria forest to the Valley Bushveld (Sub-Type 3a) is well seen. The dune belt between the sea and the hills also provides an interesting transition from the Dune Forest[1] to the Alexandria Forest. In the more arid parts the latter forest is replaced by fairly dense Acacia karroo-thornveld. In the wetter parts, e.g. to the west of Port Alfred, it tends to be replaced by almost pure grassveld.

(b) Thornveld of the Eastern Province Sub-Type

This Sub-Type occurs in the form of a narrow and irregular strip adjacent to and inland of the forest Type of the coastal belt. The original vegetation, i.e. short forest and dwarf forest, has been replaced and at present consists mainly of thornveld. Examples of the original forests only occur as narrow strips along the rivers.

2. False Bushveld Type

(a) False Thornveld of the Eastern Province Sub-Type

This veld Type is found on the undulating landscape along the foot of the mountain ranges from Debe Nek to Somerset East. This Sub-Type at present varies from Eastern Province Grassveld (Sub-Type 7a) with densely-distributed Acacia karroo to dense scrub bushveld, and False Karroid Broken Veld (Sub-Type 4b).

The vegetation of the hills and plains originally consisted of Eastern Province Grassveld (as parts are today), or scrub-forest marginal to the high forests of the mountains, and separated from the Valley Bushveld by a zone of grassy thorn and bush clump-veld along the edges of the valleys.

It is this thorn-bush clump-veld that penetrates the grassveld, decreases the grass covering and assists erosion. In this manner the way is opened for the spread of Valley Bushveld and Central Lower Karroo (Sub-Type 3e); both foreign to these parts. The result is False Karroid Broken Veld (Sub-Type 4b) which may be considered an extremely poor substitute for the short and dense grassveld. Where the dense Themeda grass has survived, no invasion by thorn trees takes place.

When the grassveld is broken down by selective grazing and is replaced by the taller and tufted grass Digitaria-Sporobolus, invasion by thorn trees takes place in leaps. Some shrubs, particularly Scutia myrtina (Bokdrol), are spread under some of these trees by birds and grow into bush clumps. As soon as these shrubs are established, grow larger and develop an undergrowth, bare spots develop around them. This condition is further aided by direct competition with the grass and by uncontrolled grazing. Erosion then takes place and all traces of the original Cymbopogon-Themeda veld gradually disappear. Re-establishment of this grass Type can only be effected by resting the veld, by reseeding and by chopping out the bush. Where erosion has not yet taken place, destruction of the bushes can lead to the immediate restoration of the grass.

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1. Acocks, J. P. H., Veld Types of South Africa, Government Printer, Pretoria, 1953, p. 74

As a result of excessive over-grazing a dense distribution of thorn trees takes place and erosion normally occurs immediately. In all cases the Karroo is inclined to invade into this area, especially along the southern and western edges. Here the Karroo vegetation is of the Central Lower Sub-Type 3e. Along the foothills of the mountains, where the rainfall is higher, the Crysocoma tenuifolia (Bitterkaroo) is the principal Karroo invader.[2]

(b) Grassveld Invaded by Thorn Sub-Type

The invasion by Acacia karroo occurs particularly in the Grassveld of the Eastern Province and arid Cymbopogon-Themeda veld Sub-Type 6a. Here the Acacia karroo can be seen as a pioneer shrub for the Valley Bushveld.

Only in the river valleys and along the foothills of the mountains does the distribution of Acacia karroo become dense enough to shade out the grass and cause erosion. The influence that veld control has on the encroachment of thorn trees may be clearly seen in the vicinity of Tarkastad and in the valley of the Koonap River, where grassveld occurs on one side of the boundary fence and dense thorn tree thickets on the other side.[3]

3. Karroo and Karroid Type

This Type, which is one of the two most important veld Types of the research area, is the distinctive vegetation of the following magisterial districts: Steytlerville, Jansenville, Aberdeen except for the north-eastern part, the eastern half of Murraysburg, southern Graaff-Reinet, the western half of Pearston, south-western Somerset East, the northern half of Albany, the greater part of Fort Beaufort, central Stockenström and the most important river valleys of Alexandria and Bathurst.

Altogether six Sub-Types are found within the above-mentioned districts, viz. Valley Bushveld, Noorsveld, Succulent Mountain Scrub (Spekboomveld), Karroid Broken Veld, Central Lower Karroo and Succulent Karroo. These are too small to show upon the map without greatly impairing its clarity.

(a) Valley Bushveld Sub-Type

As the name indicates, this veld Type is found mainly along the many south - east - flowing rivers and forms the distinctive vegetation of the Great Fish, Kowie, Bushman's, Kariega and Kat River valleys. Of the river valleys mentioned, the wide and flat Great Fish River valley covers the greatest area, and here the Valley Bushveld is found at a height of between 91.4 m. and 457.2 m. above sea-level. This Sub-Type is especially adapted to the distinctive local conditions of high temperature and meagre rainfall. In its natural state the Valley Bushveld is particularly dense, semi-succulent, thorny scrub of between 1.8 m. and 2.4 m.

2. Ibid., p. 74
3. Ibid., p. 76

in height. Over-grazing over large areas has led to the intrusion of the Opuntia (Prickly Pear) and Euphorbia bothae (Noors).

Along the Second Escarpment, on the northern side of the Great Fish River valley and where the valley constricts and is lower-lying, as well as in the side-valleys of the Kat and other rivers, there is a fringe of Valley Bushveld. On the warmer southern side of the Great Fish River valley there is, however, little growth of Valley Bushveld, except in a few of the ravines where the shrubs are less thorny and succulent. With increase in height above sea-level, it thins out to small groups of bushes, eventually going over into the scrubforest of the Grahamstown plateau. Through the encroachment of Karroo, Renosterbos and Fynbos and the destruction of scrubforest, however, this pattern is fading. At the bottom of the valley the scrub has been encroached upon and in some parts even replaced by the Central Lower Karroo Sub-Type 3e, while spots of Pteronia icana (Vaalbos) are forming on the higher slopes. Succulent and thorny patches are thus of great importance in this veld Type.

Themeda trianda (Rooigras) occurs on this veld, even where the vegetation has been broken down to False Karroo along the stony slopes lower down in the Great Fish River. The presence of this grass indicates that, with the necessary control, it can be established in the place of shrubs. Along higher-lying parts on the southern side of this river valley, where the rainfall is a trifle higher and the temperature is not so high, grassveld and grassy savanna have as a natural phenomenon followed the shrubs in inverse succession. The usual sequence is for shrubs to replace grassveld.

This region exhibits the remarkable phenomenon that it is being taken over by Danthonia disticha (coarse tufted grass) before Karroo encroachment takes place, and shows similarity to Karroid Danthonia Mountain Veld.[4]

(b) Noorsveld Sub-Type

The Euphorbia caerulescens (Noors) is found mainly beside the Middle Sundays River, north of the Grootriver Heights and Zuurberg, and in the Jansenville magisterial district. On the northern slopes of these mountains and the foothills to the north, it merges into Spekboomveld, while on the plains to the west and east, and north of the hills, it is bounded by Karroid Broken Veld. Height above sea-level varies from 304.8 m. to 609.6 m., and the rainfall is approximately 250 mm. decreasing westwards.

Even in these dry regions Karroo encroachment takes place by different species, e.g. Pentzia incana (Ankerkaroo) is found on the stony eroded open spaces.[5]

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4. Ibid., p. 81
5. Ibid., p. 84

(c) Succulent Mountain Scrub (Spekboomveld)

This Sub-Type is found mainly along steep, sandstone, quartzite and shale mountain slopes in the magisterial districts of Graaff-Reinet, Pearston, Steytlerville and to the north of Jansenville, where the rainfall is in the region of 225-300 mm. per annum.

This is a typically dense succulent bushveld dominated by Portulacaria afra (Spekboom) which averages some 1.83 m. in height. Westwards the occurrence of other species decreases. At the western boundary of this Sub-Type the vegetation consists entirely of Spekboom. Along the southern slopes the Spekboom is rare and often completely absent, and the vegetation here is non-succulent shrubs or even scrub-forest.[6]

In the north-east, where the Noorsveld fringes Bruintjieshoogte, Tandjiesberg and the mountain range around Graaff-Reinet, it merges upwards into the Karroid Danthonia Mountain Scrub (Sub-Type 6b) or False Karroo. In the Jansenville area and in some valleys of the Grootriver Heights it gradually merges downwards into Noorsveld. Elsewhere it ends suddenly at the edge of the Karroid Broken Veld and Succulent Karroo. The scrub along the southern slopes is nearer the False Fynbos in character, but stands taller and denser, varying from semi-succulent Renosterbosveld to complete, scrub-forest, similar to the upper boundary of the Valley Bushveld.[7]

(d) Karroid Broken Veld Sub-Type

The main variations of this Sub-Type are respectively: Great Karroo, the Little Karroo and Grassy Mountain Scrub.

Of these three it is especially the Great Karroo variety that is of importance here, and it is found south of Aberdeen, south-west of Pearston and in relatively narrow strips in the vicinity of Steytlerville. The occurrence of succulents is relatively small, while grass-species are surprisingly abundant. This variation is normally found on undulating stony plains, with a rainfall of between 125 and 200 mm. a year and reaching its maximum during the summer months. The height above sea-level varies from 450 m. to 1000 m.

Very little remains of the original vegetation. The present vegetation consists of sparsely distributed Karrooveld and dwarf scrub, particularly in stony parts, and thornveld along the water-courses. The occurrence of Heteropogon (Steekgras) in the Karroo portion of the research area and Themeda grass along the foot of the Nieuveld Escarpment where the rainfall is scanty, raises the question of what the original vegetation of the vleis must have been if the stony parts are capable of supporting these grasses.[8]

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6. Ibid., p. 85
7. Ibid., p. 86
8. Ibid., p. 87

(e) Central Lower Karroo Sub-Type

This veld Type is related to the Arid Karroo Sub-Type and is found between Aberdeen and Pearston. Distinct from the Arid Karroo, the Central Lower Karroo is situated on a slightly lower level, from 725 m.-1000 m. above sea-level, and where the annual rainfall is 75-100 mm. and higher. The flora corresponds largely with that of the Arid Karroo, but is shorter and more dense, at times so dense that it almost forms a complete cover. The low, stony ridges here form transition areas to the Karroid Broken Veld.[9]

(f) Succulent Karroo Sub-Type

This is the characteristic vegetation of the low-lying, warm and dry areas, e.g. the valley of the Gamtoos River to the south of Steytlerville. Here the rainfall varies from 50 to 200 mm. per year, and the height from 0 to 600 m. above sea-level.

The dominant vegetation is succulents, mainly Mesembryanthemums (Brakbossie) together with a few trees or large shrubs, except beside the rivers, where especially Acacia karroo and other related species are found. The presence of the Mesembryanthemum-species is most probably an artificial condition resultant on over-grazing and wind-erosion.[10]

4. False Karroo Type

The False Karroo Type is the main veld Type of by far the larger part of the Midlands and is widespread in the following magisterial districts: Cradock, Middelburg, Maraisburg, west-central Tarkastad, south and south-western Steynsburg and the western part of Noupoort. This veld Type is, however, not restricted to the Midlands, but also occurs in large areas near the western boundary of the Coastal Plateau, i.e. Somerset East, and narrow strips of Albany, Bedford, and south Adelaide. To the south of the Second Escarpment, False Karroo occurs widely in central Graaff-Reinet, north-eastern Aberdeen, eastern Pearston and a large part of Murraysburg.

(a) False Upper Karroo Sub-Type

This Sub-Type is the characteristic vegetation of the northern plain-area of the Midlands, with Middelburg, Steynsburg and Maraisburg as the most important districts.

In appearance this veld does not differ much from that of the Central Upper Karroo,[11] except that it is more grassy in the eastern parts. The south-eastern part of the False Karroo Type, in the basin of the Upper Fish River and its various tributaries, differs somewhat from the rest, in that encroachment by Central Lower Karroo Sub-Type 3e occur along the Great Fish River. There is accordingly a greater ratio of succulents in the False Karroo.

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9. Ibid., p. 101
10. Ibid., pp. 102, 105
11. Ibid., p. 92

The False Karroo Types are inclined to be more sparse than the genuine Karroo Types, especially in the vicinity of the upper boundary.[12]

(b) False Karroid Broken Veld Sub-Type

There is a large measure of correspondence between this veld Type and the Great Karroo variation of the Karroid Broken Veld, except that it occurs in less arid regions and is taller, denser and slightly less desert-like.

Origins:

i. From Aberdeen up to Bruintjieshoogte, all along the foot of the mountain ranges and along the Great Fish River valley up to Cradock, it is most probably the result of the encroachment of Central Lower Karroo and Karroid Broken Veld.

ii. In the lower parts of the Upper Fish River basin to the north of Cradock, it is most probably the result of the distribution of elements of the Grassy Karroid Broken Veld scrub from the mountains and of encroachment by Central Lower Karroo in the Dry Cymbopogon-Themeda veld Type, together with the destruction by overgrazing of the grassveld.

iii. In the same region, along steep mountain slopes and the valleys of the Great Fish River and tributaries towards Grahamstown, it is the result of thinning or destruction of the Valley Bushveld, Spekboomveld (Succulent Mountain Scrub) and Fish River Scrub, and the selective grazing of the grassveld associated with these veld Types, together with the encroachment of Central Lower Karroo. The campaign for the destruction of prickly pears further contributed to the spread of this veld Type.

iv. Along the foot of the mountain ranges, from Somerset East up to Debe Nek, it is a result of the destruction of the grassveld and encroachment by Acacia karroo from the south-east and Central Lower Karroo and Central Upper Karroo from the west.

v. In the vicinity of Middelburg there are signs of encroachment by Acacia karroo in the False Karroo of the Upper Plateau, which will result in the development of False Karroid Broken Veld.[13]

(c) False Central Lower Karroo Sub-Type

The occurrence of this Type is limited, and it only occurs in the lower and more level parts of the shallow valleys below the Second Escarpment between Aberdeen and Adelaide. It differs from the False Karroid Broken Veld in that trees and scrub are lacking, but it has the same species, and is less dense.[14]

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12. Ibid., p. 114
13. Ibid., p. 115
14. Ibid., p. 116

(d) Karroid Danthonia Mountain Veld Replaced by Karroo Sub-Type

This veld Type is also classed as a False Karroo Type and is found on the mountain ranges between Murraysburg, Somerset East and Cradock. This veld Type develops mainly in the valleys and ravines where there is heavy and continuous grazing. In some of the lower parts of the Second Escarpment it has already reached the mountain tops where it changes to a semi-succulent Type with scrub-like Ruschia species (vygies).

Along the lower boundary it cannot be distinguished from the normal False Upper Karroo or False Lower Karroo along the southern slopes of the mountains, except for the occurrence of clumps of Danthonia disticha (coarse tufted grass) and relics of Karroid-Danthonia Mountain Veld. Along the higher-lying parts it does, however, have distinctive features, and is inclined to be taller and go over to False Karroid Renosterbosveld.

Here there are normally relics of Danthonia disticha, (Koperdraad-gras) Themeda triandra (Rooigras), Cymbopogon plurinodis (Polgras), Aristida diffusa (Besemgras) varieties, Eragrostis chloromelas (Vleigras) and Erogrostis lehmanniana (Vleigras in Eastern Cape). The abundance of these species depends on the completeness of the replacement of the grass-veld by Karroo.

A characteristic of this veld Type is that soil erosion is incessantly removing the black vlei soil from the mountain valleys.[15]

5. Temperate and Transitional Forest and Scrub-Types

(a) Dohne Sourveld Sub-Type

The Dohne Sourveld is found in the Winterberg and its southern foothills and on the southern slopes of the Bosberg to the north of Somerset East. This sourveld region lies between 600 m. and 1,300 m. above sea-level, in an area with a rainfall of 750-1000 mm. p.a. and where snow appears only on the mountain tops during winter.

Along the Amatola mountains and along the ranges westwards to Somerset East relics of forest, compared with that of the Highland Sourveld, are more numerous, larger and better preserved. Some of these mountains are still covered with forest from top to bottom, though much of it has been reduced to scrub forest. The dominance of Podocarpus (Yellowwood) justifies the name "Temperate Forest".

The forest also shows a resemblance to the Fynbos of the Highland Sourveld.[16] The Fynbos occurs on stony outcrops on the grassy hilltops and in particular along the upper forest margin. The Dohne Sourveld that replaces this forest is also a dense, sour grassveld. This grass also shows a marked degree of variation because it is a transition type of the wetter upper margin of the Karroid Danthonia Mountain Veld in its westward extension to the Katberg, Winterberg and Bosberg.[17]

15. Ibid., p. 118
16. Ibid., p. 123
17. Ibid., pp. 74, 75

6. Pure Grassveld Types

(a) Dry Cymbopogon-Themeda Veld

The Pure Grassveld Type is found on the upper plateau between 1000 and 3000 m. in regions that are too dry for the development of forest or are subjected to heavy frost.

The Dry Cymbopogon-Themeda veld consists of a total of four variations. The south-eastern variation that is found to the east of Tarkastad, is characterised by the encroachment of Acacia karroo.[18]

(b) Karroid Danthonia Mountain Veld

In the Fish River catchment area the Pure Grassveld Type is represented by the Karroid Danthonia Mountain veld, that fringes the entire Midlands plateau area, as well as the inland slopes of the Winterberg and Katberg. The magisterial districts where this veld Type generally occurs are the greater part of Steynsburg, Tarkastad, northern Somerset East, south-western Cradock, the northern half of Graaff-Reinet and parts of Murraysburg, Middelburg and Noupoort.

The dominant grass is Danthonia disticha, and although it may be the naturally dominant in rocky sandstone parts, it is possible that Themeda and Tetrachne are the natural dominants in the dolerite parts.

In the wetter parts, e.g. Winterberg, this veld exhibits a transition to Festuca-Themeda Mountain Veld and Dohne Sourveld.[19] The scrub species occurring in this veld are the same as the False Karroid Broken Veld, but Fynbos is at times surprisingly abundant, e.g. along the Bamboesberg, although important groups such as Proteaceae (Suikerbos) and Rutaceae (Boegoebos) are lacking, e.g. along the Bamboesberg. A sparse semi-succulent vegetation is typical of the bare surface area especially where dolerite is exposed, even on the mountain tops.[20]

Under high rainfall conditions along the wetter slopes of the Winterberg, Cymbopogon is at times dominant. On the lower-lying parts the veld is largely sourveld and consists mainly of the following grasses; Themeda Forskalii (Rooigras), Cymbopogon excavatus (Terpentyngras) and Cymbopogon marginatus (Koperdraadgras).[21]

7. False Grassveld Types

(a) Eastern Province Grassveld

From surviving good samples it appears that this is one of the densest grassveld Types of the Republic, and it is mainly found at the foot of the mountain ranges from Bruintjieshoogte in the west to Debe Nek

18. Ibid., p. 129
19. Ibid., p. 141
20. Ibid., pp. 140, 141, 142
21. Preller, J. H., Veldbeheer in die Suid-Oostelike Grensdistrikte van die Kaap-Provinsie, Boerdery in Suid-Afrika, Jan. 1946, p. 41

in the east. The rainfall varies from 350-1000 mm. per year and falls mainly during summer. Under conditions of selective over-grazing this veld is broken down and encroachment by Thornveld and Karroo takes place.[22]

8. False Sclerophyllous Bush Type

(a) False Macchia (Skyn Fynbos)

The greater part of this veld Type is nowadays not distinguishable from the genuine Macchia or Fynbos but there are sufficient indications that it can in its natural state be considered a transition from the Dohne Sourveld to the Macchia.[23]

9. Summary

(a) Karroo Encroachment

The vegetation at present growing in the research area is described in the preceding discussion, and attention is drawn repeatedly to the fact that inferior plants start encroaching once the veld is unwisely exploited.

The vegetation of South Africa reveals two interesting facets, namely:

i. While it is the normal tendency for vegetation, according to the process of succession, to try to move to drier areas, Fynbos and Karroo tend to move eastwards to areas of higher rainfall.

ii. Two totally distinct types of flora are to be found in South Africa, namely the Sclerophyll (southern Fynbos) and winter-rainfall-region bush, and the tropical bush, savannah and grassveld of the summer rainfall region. "Although entirely different in nature and origin, they are today almost inextricably mixed, and have co-operated to produce that quite distinct vegetation Type, the Karroo with all its variations".[24] While tropical vegetation tends to move southwards and westwards, it is particularly the rapid eastward and northward encroachment of Fynbos and Karroo, that has assumed disquieting proportions.

In the opinion of Acocks[25] it is reasonably certain that climatic conditions have changed in South Africa in the course of several thousand years, and one can safely assume that vegetation must have undergone corresponding transformations. However, the nature of this transformation in South African vegetation, particularly during the last 100 years is such that it cannot be ascribed exclusively to the influence of natural factors.

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22. Acocks, J.P.H., op. cit., p. 150
23. Ibid., p. 154
24. Acocks, J.P.H., op. cit., p. 2
25. Ibid., p. 5

Acocks' thesis, based both on indirect historical evidence (travel literature and verbal accounts) and direct evidence (empirical research), is that the vegetation in the research area, just before white and Bantu settlement occurred at the Cape, was roughly as follows:

i. Sweet grassveld comprised a major portion of the research area (the present magisterial districts of Cradock, Graaff-Reinet, Maraisburg, Middelburg, the eastern half of Murraysburg, Noupoort, Pearston, Somerset East, Steynsburg and Tarka).

ii. Bushveld (the present magisterial districts of Jansenville, the northern half of Albany, sections of Fort Beaufort, Graaff-Reinet, Somerset East and Steytlerville).

iii. Forest and scrub-forest (present magisterial districts of Adelaide, Alexandria, Bathurst, Bedford, Stockenström and Victoria East).

iv. Karroo (including Karroid bushveld) comprised only a small part of the research area (present magisterial districts of Aberdeen, the western half of Murraysburg, and the central west-eastern section of Steytlerville), compared with its present dispersal.

When this data is compared with present vegetation (See Map No. 15), the essential differences can be briefly summarised as follows:

i. Karroo, Karroid Fynbos and Karroid broken veld have spread eastwards, northwards and up into the mountains, thereby partially or totally ousting the sweet grassveld, scrubby mixed grassveld and bushveld which formerly covered large areas.

ii. Arid types of Karroo moved eastwards to mix with less arid Karroid types.

iii. Fynbos (including Coastal Renosterveld) has spread over the entire coastal region, as far east as Grahamstown, largely replacing scrubby grassveld, scrub forest and short bush-clump veld. Fynbos is at present assailing the sour grassveld of the Amatola Mountains.

iv. Forest and scrub-forest have been largely supplanted by sour grassveld, and at lower altitudes by thornveld.

In addition to these more general changes, there are still the internal changes within each veld-type. The most serious change in all these Karroo and Fynbos Types is that perennial grasses are becoming rare or have even died out completely. In general, moreover, in all veld-types the more valuable species of grass, Karroobush and shrub have become scarcer, and have been replaced by less valuable species or even by sandy wastes.[26]

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26. Report of the Desert Encroachment Committee, Government Printer, Pretoria, (1951), p. 6

Acocks states that unless this drastic deterioration of the veld is effectively arrested, what is at present Karroo and Semi-Karroo will degenerate within the next 100 years into practically desert-like Semi-Succulent Karroo. In addition, the consequences of this degeneration will be an eastward encroachment of Semi-Karroo; as far as the present boundary of Karroo patches, running close to 28° east longitude. Acocks demonstrates that reclamation can be achieved by applying sound farming techniques and insists on its importance: "... the vegetation will have to be reclaimed before any sort of stability in South Africa's agriculture can be reached".[27]

i. <u>To what can the deterioration be ascribed</u> ?

It is certain that a deterioration has taken place. It is vital to the future prosperity of South Africa that, wherever possible, the causes of this transformation be discovered. It is possible to bring effective scientific reclamation techniques to bear once the causal factors have been ascertained. "Nearly all the changes brought about in the vegetation and in the soil can be shown to be directly related to the way in which man has used the land."[28] In the research area, natural conditions are in so delicate a state of equilibrium, and are so sensitive, that this balance may be disrupted by the application of even the most favourable agricultural techniques.

The switch-over from the unrestricted movement of wild-life to farming stock in fenced-off camps without a suitable system of veld conservation, is one of the chief causes of the veld's deterioration. This has resulted in selective over-grazing, a destructive trampling of the veld and other abuses that can be associated with such a system. Simply reducing herds will not necessarily improve the condition of the veld.[29]

Since wild life has been permanently supplanted by stock farming in the research area, it would appear impossible to restore the vegetation to its original state. "Efforts should, therefore, not be directed towards a futile task of restoring the veld to what it may have been before the arrival of the European, but much rather towards attaining the optimum level of production without permanent injury of the veld."[30]

Besides damage which can be ascribed directly to human activity, there is a distinct possibility that there may be secondary influences which have resulted in a further degeneration of the veld. These include the following:

(i) Disturbance of the soil-water relationship.

(ii) Increased aridity as a result of gully-erosion, which in turn leads to a decrease in the moisture content of the soil, especially in valleys and valley slopes.

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27. Acocks, J. P. H., <u>op. cit.</u>, p. 9
28. <u>Report of the Desert Encroachment Committee</u>, <u>op. cit</u>., p. 22
29. <u>Ibid.</u>, p. 22
30. <u>Ibid.</u>, p. 22

(iii) Wind and water erosion of the top-soil in particular, as a direct result of a stripping of the protective vegetational covering.

(iv) Possible fluctuations of the veld's capacity for reflecting solar radiation.[31]

(b) Veld Management[32]

Effective veld management consists mainly of isolating different types of veld, effecting suitable systems of grazing rotation, and instituting measures for combating droughts. Veld management has as its chief goal the encouragement of vegetation to grow as densely as possible, and to enhance as far as possible its balance of utility, quality and palatability.

i. Fencing off veld-types

The process of deterioration is chiefly due to uncontrolled or indiscriminate grazing, as well as the preference shown by different types of stock in regard to selection of species, and the selection of grazing spots or regions.

The most important of these three is the preferential selection of regions. It usually occurs when two or more veld-types in the same grazing area (or camp) differ so much from each other in general palatability and accessibility, that one becomes overgrazed and consequently weakens and degenerates.

This type of selectivity, together with species selection, is responsible for the destruction, or partial destruction, of even the best pastures, for example, vleis. When indiscriminate grazing persists and regional selection is far advanced, it is species selection which reveals itself as the most destructive process. The selection of grazing spots is basically the same as regional selection, but, by its very nature, it is localised and therefore more limited.

ii. Veld reaction to grazing

Persistent continuous grazing is detrimental to every stage in the growth of edible plants. Although all veld-types require respite, it is important that the system of grazing rotation be adapted to suit the needs of specific veld-types, in order to achieve maximum benefit.

(i) Sour Grassveld[33]

One characteristic of sour grassveld is that its nutritional value and palatability are highest while the veld is short. They decrease rapidly as

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31. Ibid., p. 22
32. Roux, P. W., Veldbeheer in die Karoo en Aangrensende Droë Soetgrasvelde (Ongepubliseerde Literatuur), Landbounavorsingsinstituut van die Karoostreek, Middelburg, 1965, pp. 1-33
33. Botha, J. P., "Resting Periods a Necessity for Sound Veld Management", Farming in South Africa, Vol. 24, Aug., 1949, p. 360

the grass grows longer. Sour veld conserved during the summer is useless for winter grazing, in contrast to sweet grassveld which can be grazed throughout the year.

Consequently the rest period should not be regarded as a means of building up grazing reserves, but rather as a measure to ensure that the veld remains in good condition. The veld should be conserved from the beginning of the growing season until its end, that is, from one winter to the next. It should be applied once every five years to sour grassveld.

The grass reserved during the growing period should be removed, either mechanically, or by burning it after the spring rains. Only then will the veld regain its value as pasture.

(ii) Mixed Grassveld [34]

In the case of mixed grassveld the resting period is of vital importance since the range in palatability to be found among individual types of grass is far greater than in the case of sour or sweet grassveld. The tendency to practise selective grazing is far greater in the case of mixed grassveld, and thus there is a danger of the tastier grasses being replaced by the less tasty ones, if the veld is not conserved or "rested" effectively.

Whether or not it is rewarding to conserve mixed grassveld for winter grazing depends on the proportion of sweet and sour grass. The more sour grass there is, the lower will be the value of this veld as winter grazing, and vice versa.

The most beneficial rest period for mixed veld is one year. After this period this type of veld can usually be used for winter grazing, provided that what remains be removed the following spring either by cutting or burning.

(iii) Karroo [35]

Persistent indescriminate exploitation, unrelieved by rest periods, has undoubtedly contributed to stripping protective grasses from large areas of the Karroo. This has led to large-scale erosion. As a result of this exploitation, several of the most tasty and nutritious shrubs and bushes, for example, Tetragonia arbuscula (klappiesbrak) have disappeared from large areas of the Karroo.

The only way in which grass and bushveld can be restored, provided they have not yet disappeared entirely, is to give each component of the veld complete protection (rest), so that each critical phase of its growth cycle may be offered full opportunity to develop safely. In practice, this protection can be effected by practising grazing rotation, to the mutual benefit of both stock and vegetation.

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34. Ibid., p. 360
35. Ibid., p. 360

iii. Burning of the Veld

The most important areas for the consideration of veld burning in the research area are the various mountain ranges and their foothills.

It would appear, according to available data about former grass coverage and bush encroachment, that, while grass coverage on mountains was firmly established, grass fires contributed toward checking bush encroachment. Under present conditions where grassveld is largely intermittent, or even non-existent, or where it has been ousted by sour grassveld, bush encroachment can no longer be checked by fire. Because of inherent differences between various mountainous areas no general rules in regard to fire or fire control can be formulated.

Reasons for burning the veld

(i) Removal of rank, old and dead grasses.

(ii) Checking and destruction of undesirable bush.

(iii) Inducement of out-of-season sprouting which can be of benefit.

(iv) Various other reasons, such as combating the tick which causes paralysis, making the veld more accessible, clearing terrain for arable lands, etc.

Fire as a means for reclaiming veld

Fire may be used to provide better grazing. Such improvement is temporary, however, because the original problem presents itself sooner or later, usually with more far-reaching effects. Where pedological and climatic conditions are favourable, it is indeed possible to reclaim veld through burning, provided a sound policy is implemented before and after the fire.

Where it appears necessary or possible to burn veld, the vegetation should be able to be burnt completely. If this is not possible, it is essential that the veld should no longer be used for grazing, or that grazing rotation should be practised until the vegetation can be burnt clean. One of the most important factors contributing to veld deterioration, encroachment of undesirable and inferior growths, and accelerated soil erosion, is that grazing is resumed too soon after a fire.

Areas suitable for veld burning along the Koueveld Mountains, the southern Tandjiesberg, Coetseeberg, Bruintjieshoogte and Bosberg are suited to total or partial reclamation when the grass is burnt. In the remaining areas, situated in the Winterberg, Great Escarpment and Suurberg, there are areas which are reclaimable. They should, however, be regarded as isolated cases. The only areas which can be reclaimed or developed successfully by means of burning, are those whose soil was originally suitable to support perennial grasses in the existing climate, and which still bear sweet grasses - especially red grass - to some extent.

iv. Grazing rotation and special treatment

To do justice to stock farming in general, it is important to draw attention to the following factors:

(i) Adequate water supply for stock.

(ii) Veld-types should be isolated, fenced off and sub-divided as thoroughly as circumstances and water supply permit.

(iii) Livestock should be grouped, when possible, in easily manageable herds, according to the number of camps and the carrying capacity of these camps.

(iv) Meticulous application of sound rotational system(s) and veld management measures for the veld-type(s) concerned.

(v) Provision should be made against drought, for example, by cultivating plants such as Opuntia sp. (Kaalblad-turksvye) and Atriplex nummularia (Oumansoutbos).

(vi) Stock should be provided with artificial shelters wherever natural shelters are lacking.

(vii) Suitable salt licks should be provided where necessary.

(viii) Effective parasite and disease prevention programmes should be implemented.

(ix) Soil erosion should be combated.

(x) Accurate diagrams, showing new camp boundaries, improvements, etc., should be provided to facilitate planning.

(xi) Agricultural records of climate (rainfall), production, income, expenditure, etc., are essential.

A complete exposition of suitable grazing systems in the Karroo and bordering sweet grassveld given by Tidmarsh (1957) is discussed in Hulpboek vir Boere, Vol. 3 These systems are repeated - with several slight modifications and adaptations - together with new systems for specific veld-types, special applications and grazing techniques, and fully discussed in unpublished sources by Roux (1965) : Veldbeheer in die Karoo en Aangrensende Droë Soetgrasvelde.

CHAPTER II

AGRICULTURAL LAND USE

In this survey the emphasis is on agricultural land use including both crop production and stock rearing. The use of land for communication or urban development is not within the scope of this study.

This chapter attempts the description and analysis of agricultural and pastoral activities, and of their environmental requirements. The analysis is in part qualitative or chorographic, but quantitative or chorometric methods are an important element of the analytical process. The chorometric analysis includes the construction of a land use map, and the statistical analysis of the data available in the Census of Agricultural and Pastoral Production.

Cultivated lands comprise 1.96% of the research area. On this small proportion, however, the return per hectare is higher on cultivated land than on grazing lands, and cropping is not as insignificant in economic terms as the percentage of land use suggests. The small proportion of cultivated land, especially in the coastal and plateau area, supports a variety of crops, which in some cases constitute the dominant element in the farm economy.

Unfortunately different crops cannot always be distinguished from one another on aerial photographs, although orchards and plantations can easily be recognised. Since the compilation of the land use map was based on aerial photographs, a simplified classification into cultivated lands, orchards and forest plantations was used. Although the diversity of the agricultural products is not differentiated on the map, the distribution pattern of the cultivated areas can readily be recognised. A distinction between the different products is, however, an essential part of the statistical analysis which helps to assess the relative importance of the different agricultural activities. The maps based on a statistical analysis of crop and livestock combinations are therefore complementary to the land use map.

A. CHOROGRAPHIC ANALYSIS

1. Stock Rearing

(a) Sheep

Sheep farming, together with the related wool industry, is today one of the most important activities in the research area, and the dominant type of farming in the Midlands and the Eastern Great Karroo area. Wool sheep are mainly Merinos which are kept under extensive conditions for fine-wool production. Approximately 80 per cent of South Africa's wool clip is fine wool, of which 87 per cent has a spinning count of 64/70's and higher.[1] As long as the price for this product remains favourable,

1. Handbook for Farmers in South Africa, Vol. III, Government Publication, Pretoria, 1957, p. 154.

this type of farming will be preferred.

According to Thom, the first wool sheep were imported into South Africa in 1657. These sheep were of an inferior type, however, and South Africa's wool industry originated in 1789 with the arrival of 4 ewes and 2 rams from the famous Escurial Merino stud of the King of Spain. Originally, several of these sheep were donated to the House of Orange, but because the wet weather of the Netherlands did not agree with them it was decided to send some of the sheep to the Cape as an experiment. These valuable animals were first kept at Groenkloof, near the present Malmesbury, under the supervision of Colonel Robert Gordon. The breed was kept pure and multiplied rapidly. A few rams were sold to local farmers for the improvement of their flocks.[3]

After Gordon committed suicide, 26 of this flock were bought by two ships officers, Waterhouse and Kent. These were to become the foundation stock for the Australian wool sheep industry at Camden Park (near the present Sydney) under the direction of the founders of the Australian wool industry, Samuel Marsden and Captain MacArthur.[4] Marsden was, incidentally, also responsible for the importation of the first wool sheep in New Zealand.[5]

Owing to the enterprising spirit of men like Jan Gysbert and Sebastian Valentyn van Rènen. who bought rams from Gordon to improve their own flocks, the influence of the first Spanish Merinos was not entirely lost to South Africa. The pioneering work of the Van Rènen Brothers kindled the interest of their fellow farmers and encouraged them to follow their example. Thus, for instance, the partnership of J. F. Reitz and M. van Breda progressed so rapidly by systematic breeding and the importation of Saxon and Rambouillet rams from Germany and France, that they were soon able to sell good quality rams to their fellow farmers.[6]

Under British rule Escurial, Negretti and Saxon merinos were imported for the purpose of developing a suitable type of wool sheep for South Africa. With the arrival of the British Settlers in 1820 the industry expanded to the Eastern Cape. New blood was imported regularly from England and Australia.

The first agricultural society with direct interests in the research area, which decidedly strove for the improvement of wool-farming, and particularly the Merino, was founded in 1824 in Graaff-Reinet. By about 1830 the merino sheep was imported to the Cradock district.[7] As a result of the rapid increase in sheep farming, particularly wool sheep farming in the Midlands and Western Coastal Plateau Area, and the increased profit margin on purified wool, woolwasheries were founded in Cradock in 1853 and Middelburg and Somerset East in 1854.[8]

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2. Els, W. C., Evolusie van Grondgebruik in die Groot-Visriviervallei, Ongepubliseerde D. Litt. et Phil. proefskrif, Universiteit van Suid-Afrika, 1965, p. 126.
3. De Klerk, J. C. "Merino Sheep Farming in South Africa" Farming in Africa, Vo. 27, No. 312, March 1952, p. 155.
4. Ibid., p. 155
5. Handbook for Farmers in South Africa III, op. cit., p. 155
6. De Klerk, J. C., op. cit., p. 156.
7. Els, W. C., op. cit., p. 128.
8. Thom, H. B., Die Geskiedenis van Skaapboerdery in Suid-Afrika, Swets en Zeitlinger, Amsterdam, 1936, p. 189.

Already in 1862 the Midlands, and the Cradock district in particular, were regarded as an excellent pastoral area. As a result of over-stocking, and a succession of droughts and plagues of locusts, the grazing potential of the natural grazing decreased. Where formerly two sheep could be kept per morgen, there was hardly enough grazing for one in 1875. This state of affairs was furthered by the fact that fencing was largely unknown and the soil was subject to trampling. This deterioration of the veld was not limited to the Midlands and the Karroo. In the Coastal Plateau Area, in particular the magisterial districts of Somerset East, Bedford, Fort Beaufort and Northern Albany, sheep farming was the main or even the only occupation in 1862. Already in those days there was a noticeable deterioration of the vegetation which was attributed to pastoral farming, veld-fires and the destruction of trees.[9]

The evolution of sheep farming after 1895 must be seen against the background of farming specialization, advanced sheep breeding programmes, scientific and technological development, and a favourable domestic and world market for wool and wool products. During the period 1923-33 there followed particular specializations in merino sheep farming, and the period is characterised by remarkable intensification. Wool sheep in the Middelburg district, for example, increased by 74% between the above-mentioned years, while the number of cattle decreased by 67% in the same period. Scientific and technological development also contributed to the development and intensification of sheep farming in the research area, in the form of, inter alia, jackalproof fencing, camp systems, shearing sheds, better management methods, farmers' and marketing organizations, stud ram breeding, fodder production under irrigation and the application of scientific veld management and soil restoration schemes.[10]

Farming specialization caused an increase in the fleece yield per sheep. This was as follows for the Midlands: 1927 - 3.6 kg, 1928 - 4.1 kg, 1929 - 4.5 kg, and 1930 - 4.5 kg.[11] At present the average yeld is 4 - 4.5 kg. per sheep on the grassveld in the vicinity of Somerset East and Graaff-Reinet, where the carrying capacity is approximately one sheep per hectare. On the Karroo veld the yield is slightly higher, approximately 4.5 kg. per head, but the carrying capacity of the veld is lower: 1 hectare per sheep in the east and about 4 hectares where the average rainfall is only 200 mm.[12]

By 1926 the classification of wool by wool growers was still in the elementary stage, and only a small percentage of the farmers classified their wool for sales. Today it is general practice, because the farmers realise that the specialised training and courses offered and arranged for this purpose by the Agricultural Colleges are profitable.

In South Africa wool production reached its climax in 1932-33, when more than 136 million kilogrammes was produced. Apart from the factors mentioned above, this increase can also be attributed to the high wool prices obtained during the twenties. Merino farming increased during this time, and when the price of wool went down, the number of sheep was increased

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9. Els, W.C., op. cit., pp. 129, 130
10. Ibid., p. 136
11. Ibid., p. 137
12. Cole, M.M. South Africa, Methuen and Co. Ltd., London, 1966, p. 242.

to ensure the same income. This increase in numbers, together with the drought years * after 1926 and in 1932-33 (Fig. 2), led to over grazing and erosion and a continuous deterioration of the veld.[13]

After 1933 sheep numbers increased regularly for a few years, but from 1937 until the end of the Second World War there was a decrease. This decrease is mainly attributable to the low wool prices ruling during the Thirties, and the fact that while the price of wool was fixed during the War, prices of other pastoral and agricultural products rose. With the tremendous increase in the price of wool after the Second World War, there was again a gradual increase in the total sheep population to 36 million in 1953.[14] After the abnormally high wool prices of 1950-51, the price of wool fluctuated constantly as a result of the influence of international economic events on the sales of wool. Thus a worldwide textile recession and credit squeeze during the period 1967-68 caused a decrease in the price of wool, and the value of South Africa's wool exports fell to R100.3 million.[15] The average export value of wool over the past five years is approximately R116.2 million.[16] During the first half of 1968 the total wool consumption rose 2.7%, compared to the corresponding period the previous year. "This recovery in demand is expected to continue, although it is unlikely to produce substantial price increases in the near future."[17] The long-term demand appears to be assured in terms of the growing world population. The short-term demand for clothing, and therefore for wool as well, varies correspondingly with the fluctuations in the economic cycle. International monetary crises can influence the wool industry by their effect on international trade. Those countries with the greatest financial problems - Britain and France - are at the moment among the main importers of South African wool.

Merino numbers in the research area decreased also because of their selective grazing habits, which contributed to a deterioration of the veld. This state of affairs was also furthered by the low fertility and low milk yield of the merino ewes, which was caused mainly by the concentration on breeding for wool, but also by faulty nutrition and management practices. Despite the adverse factors, sheep remain the most important livestock in the research area. In the coastal area (which is not really a sheep area), merino sheep comprise 86% and more of the total sheep population, while in the Midlands and the Eastern Great Karroo area they comprise as much as 90% of the total number of sheep.[18]

(b) Angora Goats

Until 1838 the indigenous common goat, kept for meat and milk, was the only type in the area; thereafter the Angora goat, kept for its hair (mohair), rapidly supplanted the common goat, though it never threatened

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* During the drought years almost 10 million sheep died.

13. Handbook for Farmers in South Africa III, op. cit., p. 119
14. Ibid., p. 119
15. Supplementary data to the abstract of Agricultural Statistics of the Republic of South Africa., Government Printer, Pretoria, January 1969, p. 54.
16. The Standard Bank Review, No. 601, April 1969, p. 16.
17. Ibid., p. 16.
18. Els, W., op. cit., p. 138

the supremacy of the Merino wool industry.[19]

The first Angora goats were imported from Angora in Asia Minor in 1838, as a result of the mohair spinning which was started in England in 1835.[20] More than 80% of the Angora goats in South Africa are found in southern, central-southern and south-eastern districts of the Cape Province. The most important districts for Angora farming in the research area are Jansenville, Steytlerville, Pearston and the southern part of Somerset East. Angora goats are also found in some farms in the districts of Murraysburg, Aberdeen, Graaff-Reinet and the thorn bush parts of Cradock, Bedford, Adelaide and Albany.[21]

The interest in Angora goat farming increased steadily from the start, and reached a peak in 1912 when 10 million kg. of mohair was obtained from 4 million goats. Thereafter there was a gradual decline in the number of Angora goats to 1 million in 1950, and today the number is less than ½ million.[22]

This decrease was not the result of the physical environment but must be attributed mainly to the instability of the mohair market. The increased use of jackal proof fencing safeguarded the grazing of Merino sheep, and in view of its higher profitability it gradually replaced the Angora.[23] The mohair market is in the first instance determined by the women's changing fashions. Unlike the wool auctions, mohair sales are effected by private agreement between the producer and the Bradford buyer, an arrangement which has prevailed at least since 1880.[24] This procedure causes considerable dissatisfaction among the producers ; they claim that the prices are effectively dictated from Bradford and this permits fluctuations in prices.[25]

The vegetation in the districts of Jansenville, Steytlerville, Pearston, southern Somerset East and the adjoining areas is ideally suited to goat-farming, especially the Noorsveld, Succulent Mountain Veld, False Karroid Broken Veld and False Thorn Veld of the Eastern Cape. Of particular importance are the climatic conditions on the relative importance and distribution of Angora goats. The Angora requires a temperate climate as it is highly vulnerable in wet and cold conditions after it has been shorn. Unless sufficient shelter is available, substantial losses can be suffered during cold spells.[26] Proof of this are the losses suffered through abnormally high rainfall in 1928,[27] and during the cold and stormy weather shortly after the shearing season in February 1964. In 1964 over ten thousand Angora goats died of exposure in the Coastal Plateau and losses estimated at R250,000 constituted a severe blow to the Angora goat industry.[28]

It must be stressed that Angora farming in general is not to be regarded as specialised, because most Angora farmers keep other small stock as

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19. Ibid, p. 144
20. Handbook for Farmers in S.A., Vol. III, p. 284
21. Ibid., p. 285
22. Cole, M.M., South Africa, Methuen, London, p. 248
23. Ibid.,
24. Els, W.C., op. cit., p. 149
25. Wellington, J.H., South Africa, Vol. II, Cambridge, 1955, p. 76
26. Handbook for Farmers in S.A. Vol. III, p. 285
27. Information obtained from Extension Officer, Graaff-Reinet
28. Els, W., op. cit., p. 152

well. Until such time as the mohair market is relatively stable, any considerable further expansion of Angora farming cannot be expected.[29]

(c) Cattle

Until the end of the 19th century cattle were used mostly for transport purposes in the research area, and they were derived mainly from indigenous stock. During the latter part of the 18th century Dutch Frieslands were imported, while English shorthorns and Devons entered the Eastern Cape in about 1820. In 1897 the cattle herds were to a large extent wiped out by the rinderpest, and further losses were suffered during the Anglo-Boer War. The modern cattle industry therefore dates only from the beginning of this century.[30]

Although cattle played a minor part in the Midlands and the Coastal Plateau during the 19th century, repeated reference is made in reports between 1865 and 1875 to the death of large numbers of valuable cattle, caused, inter alia, by foot-and-mouth disease and contagious bovine pleuro-pneumonia. Only after the exploitation of the Witwatersrand goldfields did cattle become important as a source of cash revenue in the Coastal Plateau area. This transition area between the Coastal Plateau and the Coastal Belt, in Lower Albany, was developed into an important cattle area as early as 1820. The reasons for this were mainly the suitable grazing in the Sourveld and the doubtful value of intensive cultivation. To counteract the effects of drought, the need for growing fodder crops in this area was already felt in 1869 and experiments were carried out with turnips and hay.[31]

Only in the Coastal Belt,do cattle constitute more than 50% of the total number of livestock. The Coastal Plateau can be regarded as a transition zone. From there onwards there is a decrease in the direction of the Midlands and a noticeable decrease in the relative importance of cattle to the west. There is a striking correlation between this decrease, and the decrease in rainfall to the west (Map 9) together with the concomitant change from Thorn and Grass Veld to Karroo and False Karroo Veld. (Map 15).

The density of cattle in the research area is influenced mainly by the following factors:

Physiological Factors

With the progress of veterinary science and the extension of veterinary services, diseases and pests have been limited and brought under control, which has resulted particularly in a greater density of cattle in the coastal area.[32]

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29. Handbook for Farmers in S.A. Vol. III, p. 285
30. Cole, M.M., South Africa, Metheuen, London, p. 231
31. Els, W.C., op. cit., p. 154
32. Ibid., p. 160

Physiographic Factors

The most important physiographic factors which influence the distribution and density of cattle farming as a whole, are climatic conditions, vegetation and its nutritive value. The present density of cattle is primarily related to the availability and provision of sufficient and healthy drinking water. The greater density is therefore encountered in the Lower Coastal Plateau and Coastal strip, where more water is available than in the Midlands, and the Karroo, where the limited supply of surface water has to be augmented from boreholes.

The vegetation of the Karroo, the False Karroo and the Succulent Mountain Scrub is not suitable for large-stock farming; hence the low density of cattle in the Midlands and the Karroo. The False Thorn Veld of the Eastern Province was a particularly good cattle grazing region and as such plays an important part even today. The Valley Bush Veld of the southern coastal plateau and the Alexandria forest of the Coastal Belt are excellent cattle veld: the grazing is sweet and the forest is not only very nutritious but is a valuable complement and replacement in times of drought.[33] As a result of the deterioration of the veld, sheep farming has taken an important place in the farming system of the last few years, particularly in the magisterial districts of Bathurst, Albany and Alexandria.

Apart from the fact that the natural vegetation of the Coastal strip is suitable for large stock, the conditions for the planting of pastures are extremely favourable. The average rainfall is between 625 and 750 mm. per year and spread fairly evenly over the year, with a maximum in the summer season, so that grain grows very well. The absence of severe frosts, and a short frost season of only 30 to 60 days per year, are further favourable climatological factors for the planting of pastures. These planted pastures are mainly utilised as grazing for dairy cattle and the fattening of slaughter oxen.[34] The most important pasture types are Kikuyu,[35] Napier and Rhodes grass, while indigenous varieties such as Panicum Maximum and Digitaria - varieties provide suitable planted pastures. The presence of a considerable variety of indigenous wild clover increases the value of the variety of natural grazing.

By way of summary it may be stated that the Thorn Veld and the Alexandria Forests of the southern Coastal plateau and Coastal region are eminently suitable for cattle farming. In the more arid areas of the western Coastal Plateau area where grazing for cattle is limited, sheep and goats increased in importance. The influence of the irrigation schemes, especially in the Midlands, is striking where it resulted in greater cattle density as a result of the production of fodder and more intensive farming methods. Stud animals, which are capable of utilizing the available fodder to the greatest advantage in the shortest time, enjoy preference.[36] Together with the coastal strip and Coastal Plateau area the dairy industry is here an important economic activity.

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33. Ibid., p. 160
34. Smith, F. C. „Weiding in die Kusstreek van die Suid-Oostelike Kaapprovinsie", Boerdery in Suid-Afrika, Januarie 1936, p. 230
35. „Kikoejoe bring weiding, water en grond", Landbouweekblad, Nr. 2605, 22 Julie 1969, pp. 4, 134.
36. Els, W. C. op. cit., p. 161

i. Dairy Cattle

The original stimuli for the dairy industry date back to 1892 when the Government started showing interest and ordered an investigation into the overseas butter and cheese industry. Until 1925, when the Grassridge Dam and Lake Arthur were built, a seasonal fluctuation in milk yield in the surrounding area was caused by the seasonal fluctuation in grazing. After 1925 the seasonal fluctuations in milk yield were reduced by the production of fodder crops. As a result of the development of refrigeration facilities and improved transportation, bigger markets, such as Port Elizabeth, could be supplied with fresh milk. With the establishment of the Dairy Producers Selling Agency in 1933 prices became stabilised. The function of this Body was taken over in 1940 by the Government sponsored Dairy Industry Control Board.[37]

Measured by the average South African production of 11.9 kg. per cow per day, the Midlands is one of the most important milk-producing regions of the Republic. Although production is higher here than the rest of South Africa, there are substantial variations within certain sub-regions of the Midlands, as well as in the other parts of the research area where dairying is practised, for example the coastal area.

The high production in the irrigation area is attributed to the fact that there is sufficient fresh water and a regular supply of food because nutritious hay and lucerne are grown under irrigation.

The Coastal Plateau as a dairying region is accentuated by its historic importance, namely the fact that the first butter and cheese factory in South Africa was established near Bedford late in the 19th century, and in the irrigation areas much later.[38] At present the only cheese factories in the research area are in Cradock and Kroomie, the latter being situated between Adelaide and Fort Beaufort.

The low average yield of the Coastal strip must be attributed to the system of mixed farming. The dissected southern Coastal Plateau is furthermore not suitable for intensive irrigation utilization. Although the conditions for the cultivation of dryland lucerne are favourable in parts of the Coastal Plateau and coastal strip, many farmers are inclined to make use of the natural grazing.

The various breeds furthermore show a considerable difference in milk yield. The average production of the Friesland herds in the Thorn Veld of the Coastal plateau is 17.9 kg., which is considerably more than the breed average. The production of the Jersey herds in the same area, on the other hand, is only 8.6 kg., which is considerably below the breed average.[39] In the Coastal Belt farmers go in mainly for Frieslands because of their higher milk production. As a result of the low butter fat content of the Frieslands' milk, a number of Jerseys, Guernseys and Ayrshires were imported. Crossbreeding between Jerseys and Frieslands is practised in an attempt to increase butter fat content. Along the coast

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37. Ibid., p. 164
38. Ibid., p. 164
39. Els, W.C., op. cit., p. 164

(Alexandria) where farmers go in for intensive dairying, the average yield is approximately 13.6 kg., per cow per day. Mainly as a result of the change in vegetation, there is a gradual decline in yield and production of milk from the coast inland.

The most important marketing area for milk, especially in the districts of Alexandria and Bathurst, is Port Elizabeth. A small percentage is sent to dairies in Grahamstown, mainly from the immediate environment. The milk is mainly transported by private cartage contractors. The Co-operative Dairies in Port Elizabeth also own their own lorries which are used for the transport of milk. There are creameries at Cradock, Cookhouse and Kroomie. Due to over production on national level there are not great possibilities for future expansion.

ii. Beef Cattle

The coastal area, with its sour veld, relatively high rainfall and cool climate is eminently suitable for beef farming. The success of beef farming here is closely connected to scientific planning and proper management. Cattle are kept healthy by regular dosing and have free access to mineral salt licks. The most popular and most successful beef breed in the Coastal Belt is the Hereford because of its ability to adapt quickly and easily to a variety of veld conditions.

This breed is not selective in its grazing habits and the sour grass is particularly well utilized. In addition the breed is known for exceptionally high quality meat and this is in great demand for export purposes.[40] The tendency among the farmers of the Coastal Belt is to use the Hereford for crossing with the dairy cows or Africanders, to obtain a calf with good meat characteristics. Another popular cross is the one between Shorthorn and Africander. The slaughter cattle are fattened and slaughtered "off the veld". Between 80 and 90 per cent of the cattle (250 head per day) which are slaughtered in Port Elizabeth, come from the research area.

2. Agriculture

(a) Chicory

"For centuries man had used Chicory both for himself and his animals. Historians state that Chicory varieties were already regarded by the Roman connoisseurs as a table delicacy."[41]

During 1895 Chicory (Cichorium intybus L.) was grown for the first time in South Africa by Mr R. T. Smith in the Alexandria district on the farm known today as Hollowdene.[42] At that time there was no market

40. Ibid., p. 164
41. Radloff, G., "The Chicory Industry in South Africa", Farming in South Africa., Vol. 27, No. 312, March 1952, p. 211.
42. Ibid., p. 212

for the local product as all the chicory used in the country was imported from overseas. Consequently only small quantities were grown, mainly for domestic use. Mr Smith had faith in the development of the chicory industry in South Africa however, and persuaded some of his neighbours to grow chicory.

The dried chicory roots were sold in Port Elizabeth. The demand was rather unstable and prices fluctuated considerably. During the First World War little chicory could be imported from Europe. This caused an increase in the local production and prices reached 40 shillings per 100 lbs. After the war, the price of chicory gradually declined again as a result of the Netherlands and Belgium entering the local market. At the instigation of the chicory growers the Government increased the import duty in 1922 and again in 1931.

At the start of the Second World War there was again a marked increase in the production of South African chicory. "By virtue of powers and functions invested in it by Parliament through the Chicory Control Scheme, the Chicory Control Board which was established in 1939, declared certain areas of the Union as Proclaimed Areas".[43] Originally only three districts were proclaimed: Albany, Bathurst and Alexandria in 1940. Between 1948 and 1954 four additional districts, which fall outside the research area, were included in the proclaimed area. Legally the Chicory Control Board has to market all chicory grown in the proclaimed area. Although this crop can be grown in various parts of the Republic, commercial production is limited mainly to the areas situated in the vicinity of the drying plant near Alexandria.[44]

In South Africa chicory is grown almost exclusively for the root. After it has been dried, roasted and ground, it is used for mixing in coffee.

Before 1951 the annual production of chicory was less than 5 million kilogrammes of oven-dried roots. After 1951 the average production was approximately 18.4 million kg., while in 1966 a record harvest of 19.3 million kg. of oven-dried roots was produced. One important result of

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43. Young, B.S. "The Union's Chicory Industry", South African Geographical Journal, Vol. 41, 1959, p. 41.
44. Straatman, H.J., Bradfield, D.M., Birch, E.B. and Graven, E.H., Sigoreiproduksie in Suid-Afrika, Staatsdrukker, Pretoria, 1968, p. 1.

this overproduction is that it has been proved in the Eastern Cape that chicory can with good results be used as fodder.

A combination of the following physical factors is the most favourable for the cultivation of chicory:

i. Rainfall: early winter or summer rains to ensure an early planting season; regular rain for germination, general development and maximum root growth: 50-75 mm. per month is ideal; no dry periods during the first six weeks after the beginning of the planting season and no long droughts after that.

ii. Temperature: Moderate temperature to allow germination and growth, but not sufficiently high to cause quick evaporation.

iii. Soil: Deep, well-drained soil with abundant organic material, a sandy loam for example.

iv. Topography: Valleys and areas at the foot of slopes possibly the most advantageous.

v. Wind: No strong wind, particularly not in the early stage of the growing process.[45]

Where one or more of these optimum conditions is absent, the suitability of the natural environment for the cultivation of chicory is limited. In those parts where the natural factors are favourable but the cultivation of chicory is absent, other factors are responsible. Whitmore remarks in this connection: "The regions where a crop is grown by no means invariably coincide with the limits within which the crops could be grown - for within those limits economic expediency even more than climatic feasibility may determine the extent of production."[46] Of the economic factors labour has a determining influence on the pattern: the labour requirement for chicory cultivation is such that chicory and dairying integrate well as a farming system, while chicory and citrus or chicory and pineapples are difficult combinations. A further important factor is the transport cost to the depot. In 1955 73.5% of the total production came from growers within a radius of 30 kilometres of the Control Board and 81% from 50 kilometres from the Board. Only 1% came from places further than 160 kilometres.[47]

During the seedling stage, chicory is at its most vulnerable to insect attacks, which can cause a decrease in yield in serious cases and can even necessitate transplanting. Some of the best known insects which can damage chicory are cut worms (Euxoa segetis) and the army worm (Spodoptera Exigua) and a number of beetles and their larvae. In general chicory is not seriously attacked by diseases. Two of the most important diseases which occur in South Africa are leaf spot (Cercospora Chicorii) and Thielaviopsis basicola). The best method of combating these two diseases is to practise crop rotation.[48]

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45. Young, B.S., op.cit., p.45
46. Whitmore, J.S., "The Influence of climatic factors on the agricultural development of South Africa", South African Geographical Journal, Vol.39, 1957, p.9
47. Young, B.S., op.cit., p.46
48. Staatman, E.H., Bradfield, D.M. Birch, E.B. and Graven, E.H., op.cit., p.7.

As a result of research and farming experience it has been found that chicory yields are substantially increased by the application of fertilizers. Complete fertilizing programmes have already been drawn up and it is in the farmer's own interest to test by means of simple experiments whether it is advisable for him to follow or vary this programme. The organic material content of soil plays an important part in the determination of the yield. In spite of heavy application of fertilizers the continuous cultivation of chicory on the same soil has caused a decrease in root yield after approximately four years. This problem can be overcome by practising crop rotation.[49] Where rotational cropping includes a legume, the yields can be increased by as much as 50% by comparison with chicory which is not grown under a rotational system. The following legumes can be regarded as suitable for inclusion in rotational cropping: lucerne, lupins, soya beans, cow peas and the grasses - Rhodes grass (Chloris gayana) and lovegrass (Eragrostis curvula). All these crops thrive in the chicory area provided they are fertilized thoroughly and sound production methods are practised.[50]

(b) Pineapples

There is reason to believe that pineapples were planted in South Africa for the first time during the time of Jan van Riebeeck. Three years after he had landed at the Cape,in 1655, pineapple plants arrived from South America and were planted in the shadow of Table Mountain. Due to adverse climatic conditions, the experiment failed and it was not until approximately two centuries later that pineapples were again planted in South Africa, this time in Natal.[51]

It is almost certain that the first pineapples which arrived in the Eastern Province, came from Natal. One of the first people to be successful with the cultivation of pineapples in the Eastern Province was Mr Dobson from Uitenhage (1865).[52] These first pineapples to be planted in the Eastern Province were Queens. The Cayenne variety was cultivated locally only two decades later, and also came from Natal.
Mr Charles Purdon of the Bathurst district can be regarded as the father of the pineapple industry in the Eastern Cape.[53] He already cultivated Queens as early as 1865[54] and in 1890[55] Mr J. J. Vroom, owner of a seed and vegetable shop in Grahamstown,imported the Cayenne variety from Natal for Mr Purdon. In 1903 it was reported that pineapples thrived in Bathurst and Grahamstown.

Undoubtedly the Eastern Cape is the most important production area in South Africa at present. The area in which pineapples are cultivated runs through the research area as a belt, 30 Km. wide, stretching from Port Elizabeth to the Kei River. In 1964 between 6,000 and 6,500 hectares were under pineapples. Approximately 300 million individual pineapple plants are found in this area. The annual production has varied between 100,000 and 120,000 tons per year during the last 15 years.[56]

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49. Ibid., p. 3
50. Ibid., p. 7
51. Strauss, C. B., Pineapples in the Eastern Cape, I. S. E. R., Rhodes University, Grahamstown, Occasional Paper No. 5, 1960, p. 3
52. Ibid., p. 4
53. Van Lelyveld, L. J., "In the E. P. we produce pineapples by the ton", Farming in South Africa, Oct., 1964, p. 17
54. Ibid., p. 17
55. Strauss, C. B., op. cit., p. 4
56. Van Lelyveld, L. J., op. cit., p. 17

The pineapple plant requires a frost-free climate. In the research area they are mainly cultivated along the frost-free Coastal Belt. In the interior, where frost does occur periodically, the crop is sometimes delayed for a year or more.[57] As far as is known, all the different commercial varieties offer equally little resistance against cold. It is alleged, however, that the quality of the summer fruit is improved by a certain amount of cold weather during the winter and spring months, when the fruit starts to swell.[58]

According to Johnson (1935) prevailing temperatures between 15°and 32°C are the most suitable for pineapples. The prevailing temperatures within a definite area influence the times of planting and harvesting. In the area from the Fish River to the South, the harvest time extends from February till June; North of the Fish River it occurs approximately a month earlier. Great damage is sometimes caused by sunburn with temperatures above 35°C, together with a low relative humidity. The fruit burst and the internal tissues collapse during storage.[59]

The temperature of the soil also plays an important role, because it influences the ripening of the fruit. Thus early autumn rains can lower the temperature of the soil and delay the process of ripening. If the spring rains then also occur earlier and continue until October, the temperature of the soil may remain low for an even longer period. The root systems then remain inactive for a relatively longer period, which may consequently retard the growth and development of the plants. This occurs in particular when the temperature of the air is also low during the same period of time. As a result the harvest can be delayed from 9 to 12 months if the pineapple plants are planted late in the planting season (December till March).[60]

As a result of the way in which the leaves are arranged, the pineapple plant is able to utilize light rains and dew to the full; consequently it resists drought quite effectively. Nevertheless, an annual rainfall of at least 600 mm. is required. Too much rain, however, can also have a detrimental effect on the quality of the fruit. A high rainfall is often accompanied by high humidity and the latter decreases the danger of sunburn.

Generally, the pineapple plant and fruit are not regarded as very sensitive to damage by wind. In spite of this, considerable damage is often incurred by cold winds. In the research area damage due to wind and drift sand is particularly experienced during the autumn months. On sandy soil, the plants in the outer rows may even be permanently damaged. The fruit simply becomes brown and hard along the damaged side, and is consequently unsuitable for both canning purposes and as fresh fruit. In order to minimise the damage done by wind, windbreaks ought to be planted with discretion; the site of the land ought also to be chosen in such a way that maximum protection against the cold sea winds is obtained.[61] The main aim of the wind breaks is to change the direction of the wind. Of further importance is that the windbreaks should not be planted too close together; this could prevent the necessary movement of air during the summer months and consequently create favourable conditions for sunburn.

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57. Ibid., p. 176.
58. Ibid., p. 176.

59. Van Lelyveld, L. J., op. cit., p. 17
60. Ibid.,
61. Malan, E. F., "Pineapple Production in South Africa", Farming in South Africa, Vol. 29, No. 336, March 1954, p. 177.

Pineapples are cultivated in different types of soils in South Africa. Experience proves that Queens thrive particularly well in loamy soils, whilst Cayenne show a more ready adaptation to sandy soils. It is generally known that pineapples prefer acid soil whilst poor results are obtained from sweet or alkaline soil. It was found in the research area, that poorer results were obtained from soil which had come down from higher regions in which the degree of acidity had been decreased by application of kraalmanure.[62] The best treatment seems the application of ammonium sulphate together with calcium.

At the beginning of the 20th century the expansion of the pineapple industry was restricted by the extent of the local market. As far as the value of export pineapples was concerned, improvement came only with the termination of the First World War. The progress, however, was minimal. During the earlier thirties, and again during the Second World War, the export trade was almost terminated completely. It was only after 1950 that the value of this trade passed the R200,000 mark for the first time. During the 1953/54 seasons record prices for pineapples were obtained. This post war price increase was mainly due to the considerable decrease in the pineapple productions in the Far East. The future of the pineapple market seemed secure. Within the first 10 years after the termination of the Second World War, the production of pineapples in South Africa had increased sevenfold. The rapid growth and development of pineapple production in South Africa and Australia and the rapid recovery of the pineapple plantations in the Far East made it inevitable that a saturation point of the restricted British market would be reached; this occurred just before the 1953/54 season.

Since 1950 the United Kingdom has begun to import more and more South African canned pineapples as well as approximately 90% of the fresh fruit which is exported. During the last few years the export to Britain has tended to decrease whilst the export to West Europe, especially Germany, is on the increase.[63]

"The future of the pineapple industry in South Africa does not depend on price alone, but also on the extent to which the industry adjusts itself to those areas, whether inside or outside the Eastern Cape, where conditions are most suited to the production of pineapples ... The future market for the products of South African pineapple industry is not elsewhere but inside the borders of this country".[64]

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62. Ibid., p. 177
63. Strauss, C.B., op. cit., p. 17
64. Ibid., p. 176

(c) Fodder Crops

i. Lucerne

Lucerne is by far the most important single crop cultivated in the research area, and in 1963 it covered 43% of the surface area under tillage.

Conditions are seldom favourable for crop cultivation, especially in the Midlands and Karroo. If any attempts are made in this direction, the focus must be on the production of fodder for use on the farms. Preference is given largely to lucerne because it has a high yield per hectare, a high grazing value and it shows adaptability to the particular climate of the research area. It is used both for the production of hay and for grazing. An increasingly popular practice is the ensiling of lucerne either by itself or together with other crops e.g. maize and babala.[65]

The cultivation of lucerne and the development and application of irrigation in the Midlands and Eastern Great Karroo area are practically synonymous. Since 1963 the cultivation of dry land lucerne in the Coastal Plateau area and the Coastal Belt has become very popular. If the lucerne is cut, it can be reaped for 7 to 8 years before it has to be replaced. In the case of direct grazing, however, the lifetime is only approximately 4 years, since grazing causes the encroachment of grass.[66]

ii. Wheat

Since the earliest European settlement wheat has been cultivated to a limited extent in the research area, originally, to make the settlers self-sufficient as far as domestic requirements were concerned. At present it is mainly used for winter grazing, because the farmers fear that in dry spring conditions it will not come to maturity and it is better for them to use it as winter feed. Although wheat has gradually been replaced by lucerne as a grazing crop, it nevertheless covered 15% of the total surface area under cultivation in 1963. At present, however, wheat is cultivated in the Midlands and Great Karroo area under various forms of irrigation only.[67]

The Coastal Belt is physiographically suitable for the cultivation of wheat. Two factors in particular hamper the relative importance of wheat here:

(i) considerable damage resulting from rust. In spite of the fact that varieties which are resistant to rust are used, it has been found that these varieties only thrive for approximately two years, after which they also become susceptible to rust.

(ii) The increasing and successful production of pineapples has caused a continuing decrease in the relative importance of wheat. In 1963

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65. Laubser, J. T. A. „Verbouing van lusern volgens die droëlandstelsel", Boerdery in Suid-Afrika, Deel 26, No. 306, Sept., 1951, p. 291.
66. Information obtained from Extension Officer, Grahamstown.
67. Els, W. C., op. cit., p. 198

the cultivation of wheat was important only in Alexandria, where it covered 18% of the total surface area under tillage.[68] In Albany and Bathurst it covered only 3% and 2% respectively of the surface area under cultivation.

Wheat crops in the whole research area are unreliable. In 1960 the yield in the Midlands was 4.8 bags per morgen; * on the Coastal Plateau it was 5.1 bags per morgen and in the Coastal Belt 6.2 bags per morgen.[69] In the research area wheat is of little economic value as a cash crop.

iii. Maize

Although maize was imported to South Africa as early as 1658, it was not cultivated on a large scale for over 200 years. During this period, the demand was predominantly for wheat. The climate of the South Western Cape Province was also more favourable for the cultivation of wheat. The Trekkers and missionaries took maize with them and in this way it became known to various native tribes in the interior. "However, it was actually the British Settlers who started maize farming in the eastern districts."[70]

Being originally a tropical plant, the maize requires an average summer temperature of approximately 32°C, abundant sunshine and a considerable amount of moisture during the growing season. Maize can seldom be cultivated successfully in areas with an average annual rainfall of less than 500 mm. It is these characteristics which limit the cultivation of maize in the research area mainly to the magisterial districts of Alexandria, Bathurst, Albany, Victoria East, Stockenström and Fort Beaufort. In these districts the cultivation of maize covered the largest surface area under tillage in 1963. Although the average temperature and rainfall of the Coastal Plateau and Coastal Belt meet the requirements for the cultivation of maize, production is often thwarted by drought. In the districts of Alexandria, Bathurst and Albany, maize is mainly used by European farmers as silage. Maize, however, is the staple diet of the Bantu and is cultivated by them solely for domestic use.

3. Orchards

Although it is known that the first citrus trees arrived in Cape Town from St Helena on 11th June, 1654, no reference to the citrus industry for the following 200 years could be found. "Bahia navel trees, grafted by Mr W. Tuck of Grahamstown, were distributed in the Cape Province in 1854 and since commercial citri-culture is primarily based on trees propagated vegetatively, this date may perhaps be regarded as the beginning of the citrus industry in South Africa".[71]

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* 1 morgen = 0.8565318 hectares

68. Sim, T.T.R., Wheat Production in South Africa, Bulletin No. 334, Department of Agriculture, Government Printer, Pretoria, 1953, p. 36.
69. Ibid., p. 200
70. Vorster, P.W., "The Maize Industry", Farming in South Africa, Vol. 27 No. 312, March 1952, p. 178.
71. Raimond, H.M., "The Citrus Industry in South Africa", Farming in South Africa, Vol. 27, No. 312, March 1952, p. 178.

Citrus production in the research area occurs in two relatively outstanding production areas, namely the Kat River area, which includes the Koonap River valley north of Adelaide, and the irrigated areas in the magisterial districts of Albany and Bathurst.

The most important factors to be taken into consideration for citriculture are situation, soil and climate. Although citrus trees can withstand light frosts, there is always the danger that trees can be severely damaged or completely killed in places where heavy frosts may occur periodically. Indeed, in the Kat River region frost is the greatest danger as this area lies 500 to 600 metres above sea level and has a frost period of between 60 and 90 days.

The various kinds of citrus vary in their resistance against the cold, and the extent of the damage which may be caused will depend on how low the temperature drops and the length of time trees are subjected to such low temperatures.

According to observations made in America, exposure of orange trees to temperatures of -3.3° to -3.9°C for a period of one hour or longer, will damage the leaves and young branches; at -7.8° to -9.4°C parts of the big branches will start dying and at -9.4° to -11.1°C the temperature is sufficiently low to kill the entire tree. Of the commercial citrus variety, lemons and limes are the most sensitive and their leaves and small branches can be damaged by temperatures as high as -0.6° to -1.1°C. Lemons are more sensitive than oranges and at the temperatures quoted above for oranges, the damage in the case of lemons will therefore be considerably greater. The flowers and young fruit of all citrus varieties are approximately equally sensitive and exposure for short periods to temperatures of -0.6° to -1.1°C is sufficient to kill them. Ripe fruit is approximately as sensitive as leaves and has a freezing point of about -2.2° to -2.8°C.[72]

Citrus grows quite well in regions with a fairly high average temperature, but sudden rises to abnormally high temperatures can burn leaves, cause young fruit to drop and also influence the quality of the fruit adversely. This damage is usually worse if the heat is accompanied by warm, dry berg wind conditions, especially if the immediately preceding weather was cool. Valencias, lemons and grape fruit are far less influenced by such conditions than, for example, Washington navels.

Within the limits of maximum and minimum temperatures in which citrus can be grown successfully, the average temperature plays a part mainly in determining which kinds will probably thrive best in a certain area, and when approximately the fruit will ripen. Where the average temperature is not quite so high, and where there is a considerable difference between winter and summer temperatures, varieties like the Washington navel usually yield bigger harvest, and the quality of the fruit tends to be higher as well. Experience furthermore indicates that relatively cold winters are apparently beneficial to this variety. The citrus regions in the research area are more in accordance with these climatic requirements than the subtropical climate of the Eastern Transvaal Lowveld and are consequently more suitable for navels.[73]

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72. Naude, C. J., „Sitrusverbouing", Boerdery in Suid-Afrika, Deel 29, No. 336, Maart 1954, p. 169.
73. Ibid., p. 170

In the parts of the Coastal strip with a higher rainfall, attempts have been made to grow citrus under dry land conditions. The increased need for water when the trees start bearing, made the provision of irrigation water essential. This experiment proved therefore that citrus cannot be grown successfully in even the high rainfall parts of the Coastal strip, because citrus requires the equivalent of between 750-1000 mm. of rain per year.[74] Most of this water is required from July/August (just before flowering) until March. If therefore there is not a regular monthly precipitation of at least 76-100 mm. during this critical period, and for the rest of the year at least 25-50 mm. per month, it must be regarded as insufficient. If there is enough irrigation water, rainfall does not influence the cultivation of citrus to the same extent. It can be grown equally well in places where the rainfall varies between 130 mm. or less, and 1500mm. and more. A high relative humidity and a high rainfall may however have an influence in certain circumstances. Because of a number of diseases which attack the trees and the fruit, lemons for instance cannot be grown in Florida where the humidity is high and the rainfall in excess of 1500 mm. In South Africa black spot in lemons is more prominent under more moist conditions. The relative moisture and rainfall can therefore often decide which variety will thrive best in a certain area.

The physical properties of the soil are more important when planting citrus trees than the chemical properties. A distinctive characteristic of citrus trees is that their roots need much oxygen and well-drained soil is therefore a prerequisite.[75] In the Bathurst-Fish River area citrus orchards are found on the relatively fertile alluvial soil. Away from the Fish River, in the Bathurst and Albany districts, planting of citrus is limited to small strips in valleys. This soil type is mainly alluvial originating from the Dwyka formations and Witteberg quartzite. In the Kat River region the soils used for citrus are also almost exclusively of alluvial origin and consist mainly of loams and sandy loams.[76]

The physical condition of saline soil is usually not suitable for citrus. They usually contain toxic concentrations of certain salts to which citrus is very sensitive.[77] Salinization of soil is one of the biggest problems in the research area, especially along the Fish River. The considerable quantity of salts which are sometimes present in the river requires judicious irrigation and cultivation.

In 1965 a confidential economic investigation of citrus farming in the Eastern Cape, with special reference to the Sundays River Valley, was completed. According to this report there are a number of factors which can influence the production costs of citrus. It is important to attain as soon as possible a high production per hectare, as the non-bearing period of a citrus tree places a considerable financial pressure on the producer. For effective economic production of citrus over a long period the farmer must most decidedly purchase the best budwood and apply the best spacing policy, particularly in the early stage. By growing crops between young citrus trees, a general decrease in cost over a long period can be achieved.

Apart from citrus, small quantities of apricots, pears and prunes are also grown in the research area.

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74. Els, W.C., <u>op. cit.</u>, p. 203
75. Naude, C.J. <u>op. cit.</u>, p. 170
76. Els, W.C., <u>op. cit.</u>, p. 203
77. Naude, C.J. <u>op. cit.</u>, p. 170

4. Forest Plantations

There are four state-owned forest plantations in the research area: Katberg in the Stockenström district, Hogsback in Victoria East, Fort Fordyce in the Fort Beaufort district and the Alexandria plantation on the coast. The Katberg plantation is the oldest, established in 1882, and Alexandria the most recent, dating from 1914. As indicated on the land use map,three of these forest plantations are situated along the southern slopes of the Second Escarpment.

In 1968 the areas of the four forest reserves were Katberg (1030 hectares), Hogsback (709 hectares), Alexandria (311 hectares), and Fort Fordyce (306 hectares).[78]

There are five main species of pine trees which are grown in the research area; these are Pinus canariensis, Pinus patula, Pinus radiata (insignis), Pinus pinaster and Pinus caribaea. It appears that Pinus canariensis is the species best suited to conditions in the research area.

The climate of the research area is very favourable for the growth of Pinus species. There is sufficient rainfall and high enough temperatures to allow the trees to mature within forty years. (At this age they give an average of 1.4 cubic metres of saw-timber per tree.) The attention which the plantations receive during their life time is of two kinds i.e. pruning and numerical thinning. The trees are pruned in order to obtain as much knot-free timber as possible in the mature tree. In order to carry out a calculated thinning regime it is necessary to learn how to thin in such a way that a prescribed number of trees will be left to the hectare. But thinning is not purely a matter of numbers, and a large part of the skill in thinning lies in the selection of those trees which will mature best. In many instances it is desirable to remove some of the largest trees because they are defective, and to help trees which have a better form. So we may distinguish both quantitative and qualitative objectives in thinning.[79]

The trees are planted 2.7 m x 2.7 m apart and initially there are 218 trees per hectare. After 6 years these trees are pruned by removing all the side branches from the main stem to a height of about 2 metres or a third of the height of the tree. Only the best 120 trees on each hectare are pruned because in the seventh year, the trees are thinned and defective trees removed, leaving only 120 pruned trees. At 8 - 9 years, the best 80 trees are pruned to a height of $4\frac{1}{2}$ metres or half the height of the tree. At 10-11 years, the trees are again thinned and only the above-mentioned 80 trees are left. After 12 years, 60 trees in the stand are pruned to a height of 7 metres. These trees are not pruned again and some are left for the final crop. The third thinning takes place at 14-15 years when the stand is reduced to the above-mentioned 60 trees. The final thinning takes place when the trees are 20 years old and 45 trees per hectare are left standing. The final crop is cut down when the trees are 30-40 years old.[80]

78. Department of Forestry, Annual Report, Government Printer, Pretoria, 31 March 1968, p. 133
79. Hiley, W. E., Conifers;South African Methods of Cultivation, Faber and Faber, London, 1959, p. 32
80. Kopke, D., Land Use in Ward One of the Stutterheim District, Unpublished M. Sc. Thesis, Rhodes University, 1961, p. 83

The state sawmill in Stutterheim, which at present only treats poles by the creosote process, has been replaced by a private concern, Rance Limited and this sawmill handles most of the timber from the forest plantations. A small branch of this company has been established at Katberg and is the only sawmill in the research area. In the past the Alexandria forest has been too small to justify a local sawmill. It is generally recognized that private sawmills can do the job more economically than the state. Whether state or private owned, careful planning, both in the siting of the sawmills and in the time of their erection, is essential.

Most of the sawn timber is sold outside the area to manufacturing companies in other centres of the Republic. The future prospects of silviculture in the research area are promising. Due to water shortage and a moderate timber yield,the establishment of secondary industries e.g. woodpulp, which requires a vast quantity of timber, is hampered. Construction of a series of dams in the Kat and Koonap Rivers may solve this problem.

C. CHOROMETRIC ANALYSIS

1. Land Use Map

A land use map can be compiled by four methods. Two of these methods comprise a sample survey where the samples are obtained either from aerial photographs * or field surveys. A third method is to map the entire area where every field is personally visited and classified - an ideal method for a small demarcated area. The fourth method is the one that was used in the compilation of the land use map which constitutes a part of this thesis. Here the entire area was surveyed from aerial photographs.

(a) The advantages of the method used are:

i. With the aid of aerial photographs a complete coverage of the research area is obtained and an accurate location of each land use type is reproduced on the map.

ii. The total area of lands, orchards or plantations can be obtained directly from the map by reference to the proportional symbols on the map.

iii. By comparison with other methods much time is saved in that the fieldwork has been limited to the absolute minimum. For the purpose of this survey distortions due to tilting and uneven relief can be disregarded, while mistakes involving situation and extent are minimal.

A disadvantage of this method is that the aerial photographs were taken over a period of 17 years (1950-1967) and that the land use map may differ from the present pattern. Fortunately the intensive agriculture in the magisterial districts of Bathurst, Albany, Alexandria and Victoria East were photographed as recently as 1967, while the land use pattern in the rest of the research area has not changed greatly between 1950 and 1967.

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* Board, C., "The World Land Use System and South Africa", South African Geographical Journal, Vol. 42, 1960, p. 22.

JOB	533	42/43	522	446	383	459	494	560	234	545	557	334	370	570	230	523	566
SCALE	1:45,000	1:27,000	1:40,000	1:50,000	1:36,000	1:36,000	1:30,000	1:36,000	1:30,000	1:36,000	1:20,000	1:36,000	1:36,000	1:60,000	1:30,000	1:40,000	1:40,000
DATE	1965	1943	1965	1960	1956	1961	1963	1962	1950	1962	1967	1954	1958	1966	1950	1964	1966
No. of alternate Aerial Photographs	12	28	60	73	80	82	87	90	94	111	134	136	152	158	211	289	306

TABLE 9 : LIST OF AERIAL PHOTOGRAPHS

By working at Trigonometrical Survey (Pretoria) a complete coverage and full set of aerial photographs were available and stereoscopic viewing was often used where problems arose. However, in order to avoid unnecessary duplication of work most of the calculations were done on alternate photographs. In this way approximately 2000 aerial photographs were examined and the area of each individual field, orchard and plantation measured. This was done with the aid of dot planimeters. * The measurements obtained for each parcel are accurate to 0.01 of a square mile or approximately 5 hectares.

The data from the aerial photographs were tabulated as the research progressed. These tables, together with the work sheets, provided the basis for a quantitative cartographic compilation.

Work sheets were produced by superimposing tracing sheets on 1:250,000 Topocadastral maps. While the calculations were from the aerial photographs the rest of the compilation was done on these Topocadastral maps. The mapping procedure employed can be briefly summarised as follows:

i. The flight lines were drawn on the 1:250,000 work sheets.

ii. With the flight lines as a guide, the centres of the alternate aerial photographs were plotted on the work sheets.

iii. By using principal points of the photographs and the detail which was discernable on both the Topocadastral maps and aerial photographs, the boundaries of each successive photograph were determined and drawn on to the work sheets. In the mapping of these boundaries the 20% to 30% overlap on both sides of the aerial photographs was eliminated to avoid repetition in the calculation of the land use types.

iv. The situation and shape of the cultivated fields were drawn as accurately as possible within the demarcated boundaries of each individual aerial photograph.

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* The kind co-operation of Dr J.N.Scheepers at UNISA is gratefully acknowledged; he generously allowed the use of his own planimeters as patterns from which copies could be made. The method of using dot planimeters is discussed in Monkhouse, F. J. and Wilkinson, H. R., Maps and Diagrams, Methuen, London, 1964.

v. With the compilation of the final map, the situation and shape of each cultivated field were taken into account when the proportional symbols were grouped. Three different sized symbols (dots) were used, representing .01, .10 and 1 sq. mile (2.6, 26 and 260 hectares). In order to give an accurate impression of the areas involved, the symbols are true to scale, i.e. they give a correct representation of the amount of land under cultivation in relation to the total land area on the map.

Dot maps, in general, show variations in distribution admirably, but normally portray quantities very weakly, especially in areas which contain tens or hundreds of dots. This difficulty results from the use of too small a dot as the only quantitative symbol. In the case of the land use map, this problem was overcome by using three different sizes of symbols, representing areas from .01 to 1 sq. mile.

The advantage of easy interpretation of the large dot in particular is best illustrated on the land use map by the district Alexandria. As one of the most intensively cultivated districts in the research area, an accurate calculation can easily be effected by counting these dots. If, however, the .01 dots only had been used, it would have been practically impossible, as a result of the dense cluster of dots.

	JANSENVILLE	PEARSTON	NOUPOORT	STEYTLERVILLE	ADELAIDE	MURRAYSBURG	MARAISBURG	FORT BEAUFORT	STOCKENSTRÖM	ABERDEEN	STEYNSBURG	BEDFORD	VICTORIA EAST	TARKASTAD	MIDDELBURG	SOMERSET EAST	GRAAFF-REINET	CRADOCK	ALBANY	BATHURST	ALEXANDRIA	RESEARCH AREA
Area in sq. Kilometres	13.88	14.14	16.52	17.95	24.42	25.30	31.80	32.22	33.33	39.47	40.69	43.18	60.37	61.15	79.12	90.75	101.42	116.58	146.57	156.54	274.41	1419.81
%	0.30	0.55	1.11	0.49	1.58	0.47	1.34	2.51	4.10	0.57	1.49	1.65	6.32	1.91	1.58	1.61	1.49	1.96	3.33	10.64	11.25	1.96

TABLE 10: CULTIVATED AREA PER MAGISTERIAL DISTRICT, IN SQ. KILOMETRES, AND PERCENTAGE OF TOTAL DISTRICT AREA.

A further advantage of using three different sized dots is that the situation and shape of each individual field could be realistically rendered. This can be illustrated, for example, by the long and narrow fields along the river banks. The shape of these fields necessitated the use of symbols for .01 or .10 square miles.

(b) Elements of Land Use

After a preliminary survey of the research area, it was decided that the classification of the International Geographical Union (I.G.U.) had to be simplified. This was necessary because of the limited time available in which to survey this large area. A sub-division of cultivated land according to the various crop types was not considered essential, as cultivation is far less important than animal husbandry in most of the research area, and occupies only 1.96% of the total area. This pilot survey showed that agricultural land use in the research area consists firstly of extensive grazing of natural pastures (veld) and secondly of the cultivation of arable land, orchards and forest plantations.

(c) Land Use Patterns

The distribution and grouping of cultivated land, as indicated on the land use map, displays various interesting characteristics. There is a sharp contrast between the Cape Midlands and Karroo on the one hand, and the Coastal Plateau, with its relatively high rainfall, on the other. The higher rainfall on the Coastal Plateau is the main factor causing the concentration of nearly half of the total cultivated land in less than a quarter of the research area, in the magisterial districts of Bathurst, Albany, Alexandria, Stockenström, Fort Beaufort and Victoria East.

Four areas with concentrated cultivated lands, can be distinguished on the land use map: two, each with a relatively even distribution pattern, occur on the Coastal Plateau; they are, the area along the coast, consisting of the magisterial districts of Alexandria, Bathurst and southern Albany, and the area to the north of Alice. These two areas are separated from each other by the much drier Great Fish River valley with limited cultivation along the stream course. The other two areas, situated in the Midlands and Karroo, are the irrigation areas in the Sundays and Great Fish River valleys. In the rest of the research area cultivated land appears as narrow strips mainly along rivers and streams.

i. Midlands and Karroo

Two types of farming units are found along the Sundays and Fish Rivers. Firstly there are the small farms which consist exclusively of irrigation soil or both irrigation soil and pasture land. Secondly, there are the large farms which border on these rivers and which include part of the irrigation lands.

The average size of the smaller farms along the Fish River, is approximately 250 hectares. Farms as small as 70 hectares do however, occur. The main source of cash income on these small irrigation units is the cultivation of lucerne and wheat, together with dairy farming. In cases where these small farms have the necessary pasture, sheep may also be included in the farming system. Farmers with large farms along these rivers,are mainly concerned with wool sheep. The lucerne and wheat which is cultivated on their irrigated lands, is used mainly for fodder; part of the crop may, however, be sold.

In the rest of the Midlands and Karroo, cultivation is practised on a small scale. According to the Land Use map there is, except for the lands along the Sundays and Fish Rivers, a denser distribution of cultivated lands in the Midlands than in the Karroo. This difference is mainly due to the lower rainfall in the Karroo (See Map 9). The average rainfall in the Midlands is, however, not sufficient for the use of dry land cultivation and many farmers use the so-called "saaidam" system or flood irrigation.

Lucerne	Oats	Maize	Wheat	Other Crops	Pineapples	Chicory	Barley	Sorghum
43	18	16	13	3	2	2	2	1

TABLE 11 : CROP SURFACE AREA AS PERCENTAGE OF TOTAL CULTIVATED SURFACE AREA * (In the Research Area)

According to Table 11, lucerne covers 43% of the total land under cultivation in the research area. In relation to other crops, lucerne is especially favoured in the arid Karroo where it covers up to 80% of the cultivated area. To the east and south-east, there is an increase in the variety of agricultural products which are cultivated, whilst the area covered by lucerne gradually decreases. In Victoria East, for example, it covers only 6% of the cultivated area, and this percentage drops to a mere 2% in Alexandria. These varying crop combinations are discussed in detail in the next sub-section.

ii. The Coastal Plateau

The greatest proportion of cultivated land per farming unit is encountered in the area to the south of the Fish River valley, in the districts of Alexandria, Bathurst, and southern Albany. This can be ascribed mainly to climatological factors, and most of the cultivation occurs under dry land conditions.

In the previous chapters, it has already been stressed that the farming in this area is essentially mixed. The most important cash crops which are cultivated are pineapples, chicory, and to a lesser extent, citrus. Although these cash crops provide an important contribution to the farmer's income, fodder crops cover the largest portion of cultivated area. The reason for this is that the combination of livestock and fodder crops, as a farming system, generally yields a higher total farm income than the combination of cash crops and livestock.

Pineapples are found distributed in a strip along the coast. Production of pineapples on a large scale has as a direct result decreased the average production cost. At present the cultivation of pineapples is mainly on those farms with large quantities of cultivated soil suitable for this fruit. Should the price of pineapples rise again, the small farmers and those with limited quantities of cultivated soil will go in for the production of pineapples once more. At present this soil is mainly used for the cultivation of fodder crops (maize, oats, wheat and lucerne), which contributes indirectly to the farmer's income. Although the cultivation of chicory is quite widely practised, it has its highest concentration in the vicinity of Alexandria, where the drying plant is situated. Besides

* Based on data obtained from Census of Agricultural and Pastoral Production, 1963.

physical factors, this concentration can largely be ascribed to an economic factor: an increase in the transport costs with increased distance from the depot. Labour requirements for chicory cultivation are such that chicory and dairying integrate well as a farming system.

Wool sheep are found on practically every farm, whilst mutton sheep occur only in exceptional cases. Beef cattle are distributed throughout the area; they occur in greater numbers, however, to the east where the Thorn Veld vegetation is denser. Due to the proximity of Port Elizabeth as a market, most of the dairy farming occurs in the south-east of the Alexandria district; here it is one of the most important sources of farm income. Where dairy farming forms a part of the farming system, the available arable land is used mainly for the cultivation of fodder crops. The most important fodder crop is maize, which consequently covers the largest surface area under cultivation.

In conclusion it can thus be said that the farming system in these three districts is an essentially diverse one. The main source of income is either dairy farming, sheep, cattle or pineapples, but never as the only direct source of income. This tendency to emphasize one specific branch of activity, is not in any way related to the size of the farm, but can be mainly attributed to personal considerations, microclimatic differences and market advantages.

In the area to the north of the Great Fish River valley, cultivated lands are distributed throughout the districts of Bedford, Adelaide and Fort Beaufort. Sheep and cattle farming here form the most important part of the farming activity and farmers concentrate mainly on the production of fodder crops under irrigation. Of these fodder crops, maize, lucerne and wheat are the most important. It is mainly in the Kat River valley where the farms are small, that the emphasis is placed on the cultivation of tobacco and citrus as cash crops. The cultivation of citrus is concentrated mostly in the valleys of the Tyumie, Kat and Koonap Rivers.

The densely cultivated arable land to the north of Alice forms part of the Ciskeian Bantu territory; this area is in sharp contrast to the adjacent European farms. Maize is the most important agricultural product here, and covers 82% of the cultivated land in Victoria East and 44% in Fort Beaufort. This high percentage must be attributed to the fact that maize is the staple diet of the Bantu population. When Bantu cultivation is not taken into account, the percentage of arable land covered by maize cultivation, is only 39% and 7% respectively.

Regarding agriculture, there is a considerable difference between Europeans and Bantu. There may be said to be two different types of rural economy existing side by side in the same country. One is the essentially commercial-orientated farming of the white farmers, and the other is the largely subsistence-farming of African peasants in the reserves. The difference between the two is deepseated and manifests itself in a variety of ways reflecting cultural differences and fundamental attitudes to the exploitation of the natural environment.[81]

81. Hobart Houghton, D. The South African Economy, Oxford University Press, London, 1969, p. 45.

2. Matrix Model

One use of a matrix model in geography, is to enable the geographer to classify the phenomena which he is studying. This is achieved by the establishment of a logically derived set of theoretical situations, so that in any given real situation the extent of its deviation from each of the theoretical situations can be measured and expressed as an index of deviation. The theoretical situation from which it deviates least, can thus be determined as that which gives the lowest index of deviation. One of the outstanding features of this model is, that since the information is selected objectively, the same method used by different workers on the same data will give the same results. Furthermore, different studies carried out by such a method will always be comparable, irrespective of place or time.

The technique adopted in this research is that of J. C. Weaver and J. T. Coppock. The theoretical situations used, relate to the areas under different crops and to numbers of livestock. Each represents an ideal situation in which, for example, a monoculture has 100% of the cultivated area under the single crop, a two crop combination has 50% under each of two crops and thus down to a 10 crop combination in which each crop occupies 10% of the cultivated land. (See Table 12).

COMBINATIONS	CROPS 1	2	3	4	5	6	7	8	9	10
Mono-culture	100	0	0	0	0	0	0	0	0	0
2 Crop	50.00	50.00	0	0	0	0	0	0	0	0
3 Crop	33.33	33.33	33.33	0	0	0	0	0	0	0
4 Crop	25.00	25.00	25.00	25.00	0	0	0	0	0	0
5 Crop	20.00	20.00	20.00	20.00	20.00	0	0	0	0	0
6 Crop	16.67	16.67	16.67	16.67	16.67	16.67	0	0	0	0
7 Crop	14.29	14.29	14.29	14.29	14.29	14.29	14.29	0	0	0
8 Crop	12.50	12.50	12.50	12.50	12.50	12.50	12.50	12.50	0	0
9 Crop	11.11	11.11	11.11	11.11	11.11	11.11	11.11	11.11	11.11	0
10 Crop	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00

TABLE 12 : PERCENTAGES UNDER VARIOUS CROPS IN THE MATRIX MODEL

The index of deviation (x) can be expressed as $x = \Sigma d^2$ where (d) is the difference between the actual and theoretical percentage under each crop. The crops are placed in rank order before the differences are squared, and the squares summed. The theoretical situation for which the sum of the squared difference is least, is the one which the real data fit most nearly. This determines the number of elements in the combination and these are recorded in descending rank order. (See Table 13)

	M	P	O	C	L	Lu	W	Po	R	K
% of cropland occupied	24	21	17	13	8	7	3	3	2	2
%, theoretical, base curve	16.67	16.67	16.67	16.67	16.67	16.67	0	0	0	0
Difference	7.33	4.33	.33	3.67	8.67	9.67	3	3	2	2
Difference squared	53.72	18.74	.10	13.46	75.16	93.50	9	9	4	4
Sum of squared differences	280.68									

TABLE 13 : SAMPLE CALCULATION OF INDEX OF DEVIATION (Albany District, 1963)

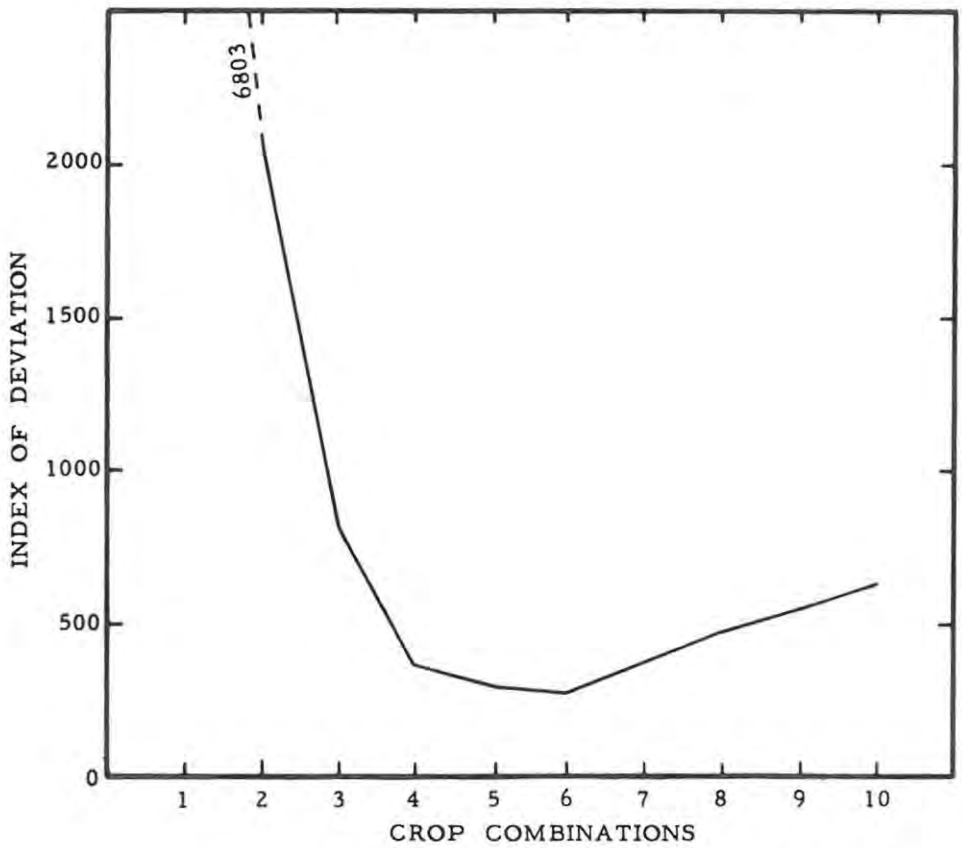
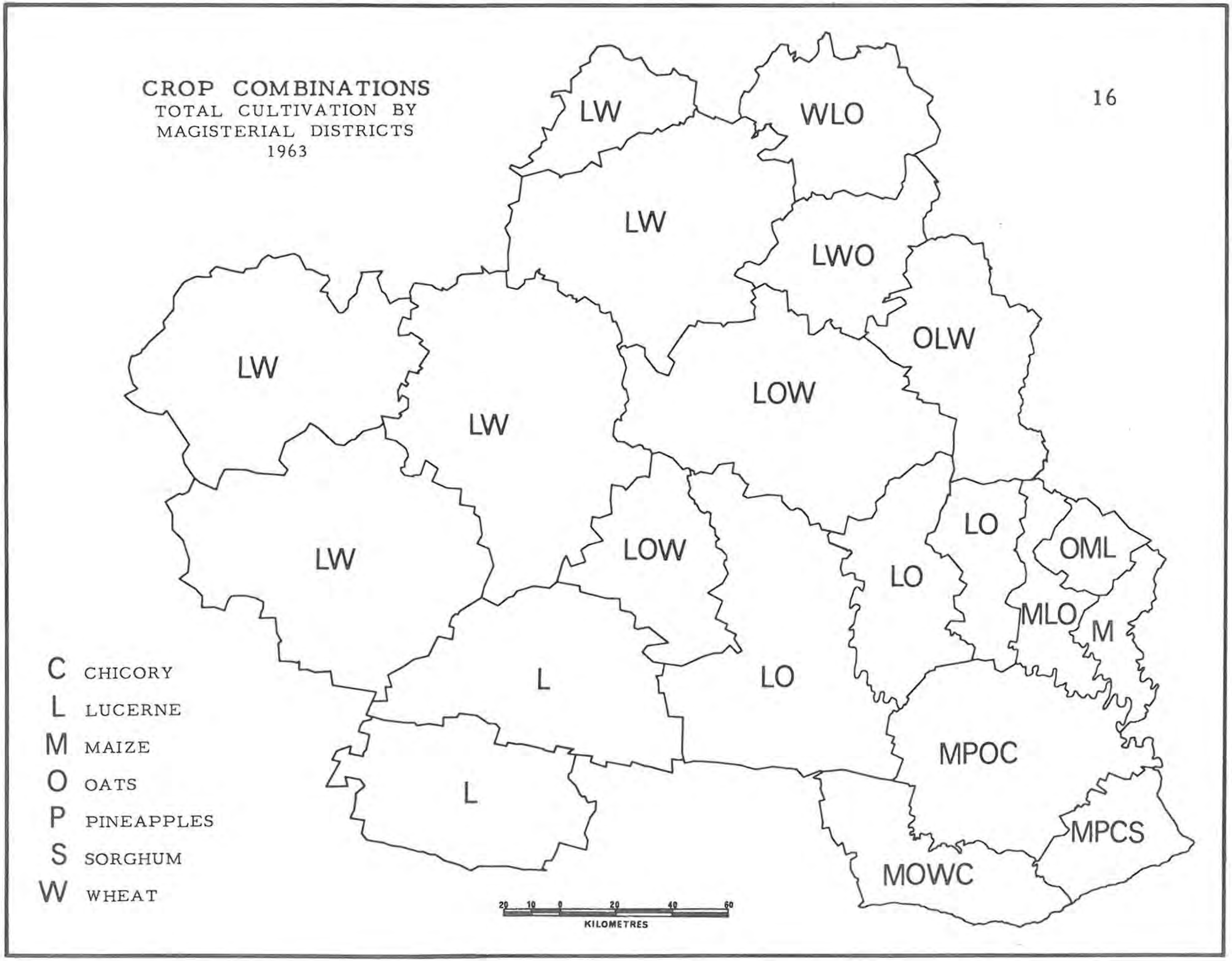
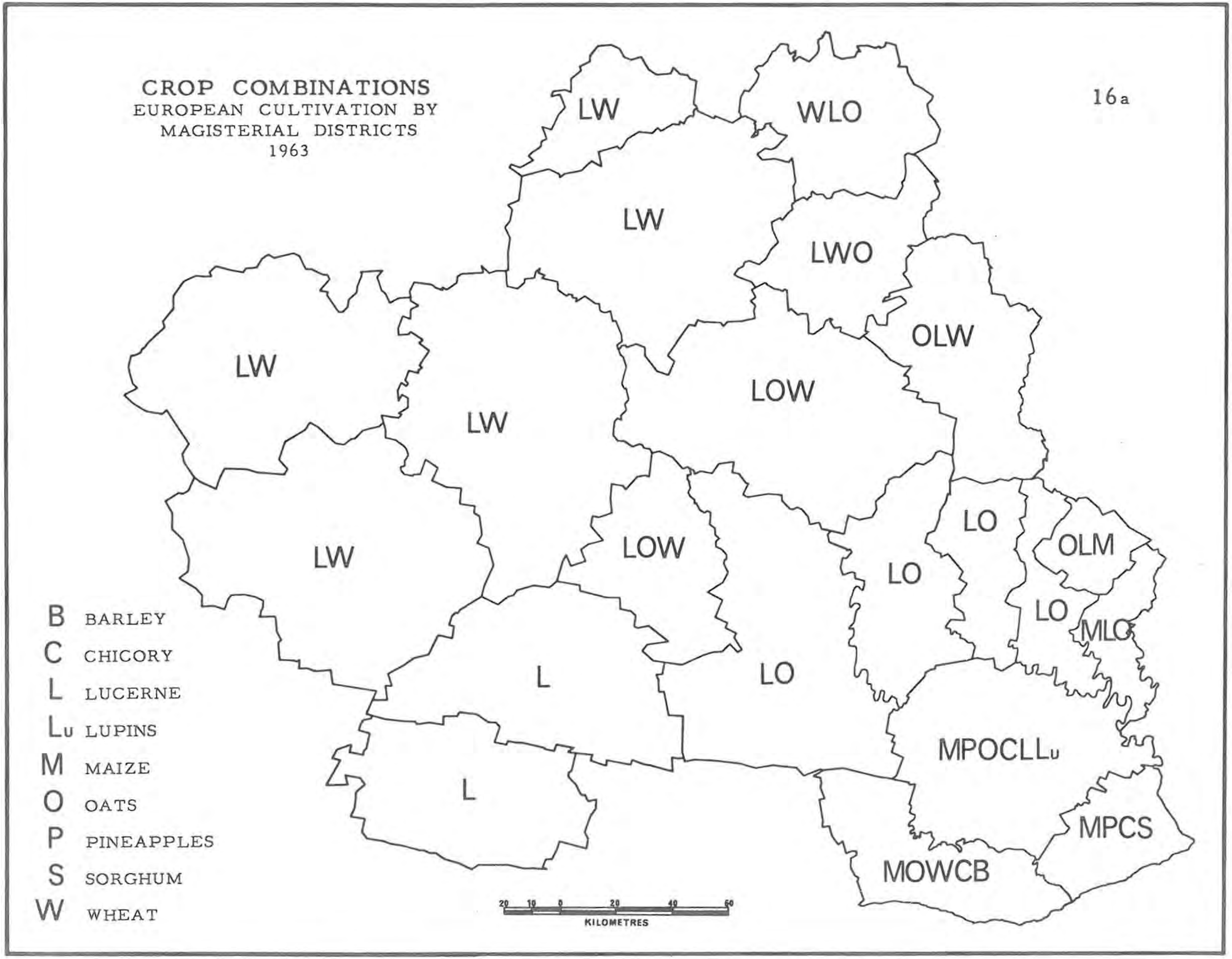


FIG. 5 : GRAPH TO ILLUSTRATE THE RELATIONSHIP OF DEVIATION INDICES FOR A 10 CROP MATRIX MODEL (Albany District, 1963)


CROP COMBINATIONS
TOTAL CULTIVATION BY
MAGISTERIAL DISTRICTS
1963
LW
WLO
LW
LWO
OLW
LW
LW
LOW
LW
LOW
LO
LO
OML
LO
MLO
M
L
LO
MPOC
L
MPCS
MOWC
C CHICORY
L LUCERNE
M MAIZE
O OATS
P PINEAPPLES
S SORGHUM
W WHEAT
20 10 0 20 40 60
KILOMETRES


CROP COMBINATIONS
EUROPEAN CULTIVATION BY MAGISTERIAL DISTRICTS
1963
16a
LW
WLO
LW
LWO
OLW
LW
LW
LOW
LW
LOW
LO
LO
OLM
LO
MLO
L
LO
MPOCLLu
L
MPCS
MOWCB
B BARLEY
C CHICORY
L LUCERNE
Lu LUPINS
M MAIZE
O OATS
P PINEAPPLES
S SORGHUM
W WHEAT
20 10 0 20 40 60
KILOMETRES

The data for Albany district, taken as an example, are used here to demonstrate the technique. In this district the actual distribution of crop percentages in 1963 was: Maize (M) 24, Pineapples (P) 21, Oats (O) 17, Chicory (C) 13, Lucerne (L) 8, Lupins (Lu) 7, Wheat (W) 3, Potatoes (Po) 2, Rye (R) 2 and Sorghum (S) 2. The deviation from the theoretical curve is the lowest for a six-crop combination, as is shown by the graph in Fig. 5.

The results obtained from these calculations are recorded on maps showing crop combinations and, using a similar method, livestock combinations may also be calculated. The resultant maps only indicate the categories in which each census district falls, and do not delimit agricultural regions. By means of these maps it is possible to obtain a clearer picture of the relative importance of different farming activities in the districts comprising the research area.

In the case of agricultural crops, areal extent is not the only criterion whereby the various combinations can be determined. In the ultimate interpretation of regional development it will be necessary to take into consideration such factors as volume of production and value, but the data are not readily available, and the accurate estimation of such quantities is no easy matter.

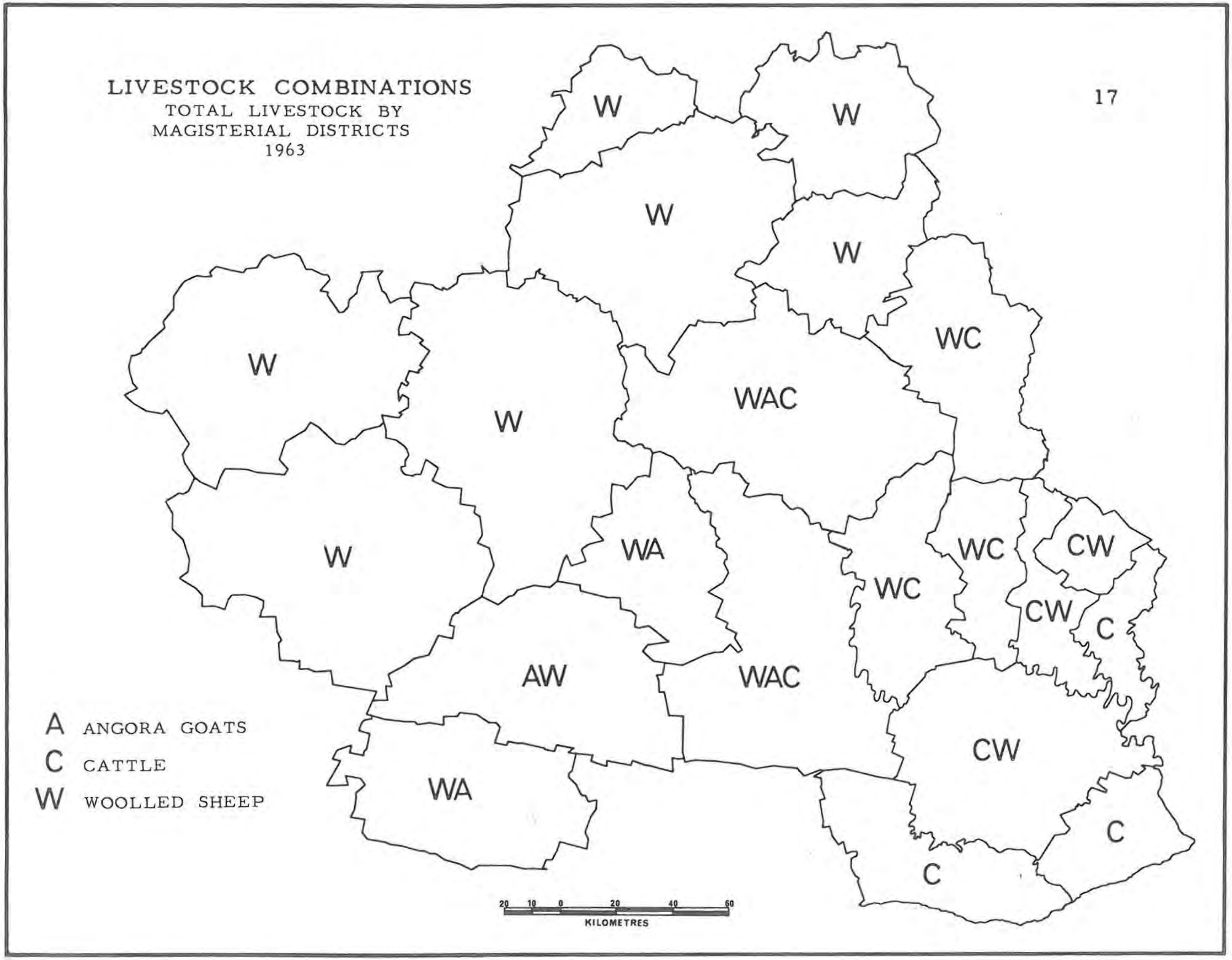
(a) Crop Combinations

Agricultural crops are often studied individually. However, it seldom happens that a specific crop is grown in complete isolation, and the normal tendency is to grow products in different combinations.

In the past, too much stress has been laid on simplified agricultural regions, named according to the dominant crop. In South Africa especially, the real state of affairs has not been analysed, nor has notice been taken of the fact that in these so called homogeneous regions, for example, the pineapple-chicory region, other crops are grown, and may occupy as large an area as the economically dominant crops. (See Map 16)

Although only 1.96% of the research area is used for crop cultivation, sixteen different crops were grown during the period 1962-63. After these crops were tested against the matrix model, some were found to be insignificant and only seven feature in the crop combinations derived. The crops concerned are represented by the following symbols:
C - Chicory, S - Sorghum, L - Lucerne, M - Maize, O - Oats,
P - Pineapples and W - Wheat.

The crop combinations vary between monoculture, Jansenville - L, Steytlerville - L and Victoria East - M. The four element combinations are limited to the areas where intensive cultivation is practised : the magisterial districts of Albany - MPOC, Alexandria - MOWC and Bathurst - MPCS. During 1963 maize occupied the largest area under cultivation in Albany, Alexandria, Bathurst, Victoria East and Fort Beaufort. The exclusion of Bantu cultivation affects only the classification in the south eastern districts. In Victoria East the crop combination is changed from a monoculture to a three element combination. In Albany, Alexandria and Bathurst the rank order of the crop was not altered, but the


LIVESTOCK COMBINATIONS
TOTAL LIVESTOCK BY
MAGISTERIAL DISTRICTS
1963
17
W
W
W
W
W
W
W
WC
WAC
WA
WAC
WC
WC
CW
CW
C
AW
CW
WA
C
C
A ANGORA GOATS
C CATTLE
W WOOLLED SHEEP
20 10 0 20 40 60
KILOMETRES

number of elements in the combination is increased. This difference is significant in that it shows the contrast between the system of European and Bantu cultivation. While the Bantu peasant depends heavily on a small number of crops, the agricultural activity of the European farmer involves a wider range of crops.

When Map 16 and Map 17 are compared, the predominance of lucerne in the magisterial districts where wool sheep are in the majority, is quite striking. In these districts where lucerne is the most important crop, this trend is maintained. The position of wheat and oats in the combination however, varied considerably. Wheat has the advantage over oats in that it can provide winter grazing for livestock, and can still provide a saleable grain crop.

(b) Livestock Combinations

In the case of stock rearing, it was necessary to express the total numbers in the same units, since it is evidently nonsense to equate the different species numerically. The weights used, are the units employed by the Department of Agriculture. (1 unit is equal to 1 cow, horse, donkey or mule; 5 pigs, 4 ostriches, 7 sheep or 7 goats). These units are based upon average feed requirements of the various species.

In the calculation of the various combinations and compilation of Map 17 the following code letters have been employed: A - Angora Goats, C-Cattle and W - Wool sheep. On Map 17 the livestock combinations for the total number (White and Bantu) for each magisterial district have been portrayed. "While there are differences, probably the most remarkable feature is the extent to which the inclusion of Bantu-owned animals fail to alter the classifications, especially in the eastern half of the country".[82] In the research area the inclusion of the Bantu-owned stock units causes a variation only in the Fort Beaufort district, where the stock combination changes from WC to CW.

Map 17 gives a clear picture of the character of pastoral farming in the research area for the statistical year 1962 - 63. The magisterial districts of Aberdeen, Middelburg, Noupoort, Maraisburg, Murraysburg, Graaff-Reinet and Steynsburg are classified as W. In the following magisterial districts, which consist of more than one element, wool sheep are also in the majority. Adelaide (WC), Bedord (WA), Cradock (WAC), Pearson (WA), Somerset East (WAC), Steytlerville (WA), and Tarkastad (WC). The magisterial districts of Alexandria, Bathurst and Victoria East, however, are classified C, while cattle play a dominant part in Albany (CW), Fort Beaufort (CW) and Stockenström (CW). In only one magisterial district, Jansenville (AW), are Angora goats in the majority. Out of the 21 magisterial districts there are only two which have a

82. Henderson, H. J. R., "Towards the statistical definition of Agricultural regions in South Africa". South African Geographical Society Jubilee Conference, 1967. p. 500.

combination of three elements, namely Somerset East (WAC) and Cradock (WAC). In comparison with the official statistical data for 1960 only Cradock has undergone a significant change. In 1960 the element combination was (WC) and in 1963 (WAC). This change, and also the decrease in large-stock units for the period 1961-63, can be attributed to three main factors:

i. As a result of the extended drought, grass in particular suffered and the carrying capacity of the veld decreased.

ii. The Government de-scheduled farms along the Fish River. This land was then let to farmers who stocked it with sheep.

iii. During this period there was an increase in Angora goats as a result of the high prices for mohair. Since 1963 there has been a decrease in the number of Angoras as a result of price fluctuations.

In the different magisterial districts of the research area, the relative importance of various farming activities is made clearer with the aid of the matrix model. However, these magisterial districts differ considerably in area and this difference is a disadvantage for any statistical analysis. The areas, furthermore, are so large that variations of phenomena within any one district are frequently lost. In most cases the geographic reality is obscured by the predetermined magisterial boundaries. An example of this is clearly demonstrated by comparing Map 16, showing the magisterial boundaries, with Map 19, a map of grazing potential. The use of a grid model offers uniform areas at a scale which is selected to suit the size of the study area.

3. Grid Model

The grid model provides a means of testing an hypothesis which, once proved, may be incorporated into an overall theory. This theory will account for the distribution and interrelationship of phenomena in a logical and consequential manner. Theories are not an end in themselves; they are but the means to a clearer comprehension of the diversity of phenomena of the earth.

This particular hypothetical model is based on a grid system of square units with each side measuring five minutes of arc (approximately 8 kms). These form the basis for the collection, comparison and definition of quantitative relationships and associations for the delimitation of "regions of minimum deviation". These regions are defined by Du Toit as follows: "Indien 'n element en al die moontlike verskynsels wat dit beïnvloed, wat die navorser by magte is om te betrek, gesamentlik en terselfdertyd deur een proses oorweeg word, sal die differensiant as minimum afwyking streke uitkristalliseer met die karakteristieke eienskap dat maksimum homogeniteit binne die streek sal voorkom". *

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* If an element and all possible phenomena which influence it spatially (which it is within the power of the research worker to obtain), are considered jointly and simultaneously by a single process, the differentiant ** will crystallize as regions of minimum deviation with the characteristic of maximum homogeneity within the region.

** A differentiant is a differentiation in the sense of the result of the differentiating process. (De Jong, G., Chorological Differentiation, Groningen, 1962, p. 5).

These grid units are approximately 64 square kilometres in size. The whole research area is covered by 1,009 units. Each observation unit is .001% of the total surface area. The relatively small size of the grid units has the advantage of giving very accurate readings, especially in regard to site. This aspect of site is especially important in the construction of the final maps, based on interpolation - the larger the number of observations, the more accurate the map.

In the case of a sample survey the results could have been statistically but not geographically significant. The problem which arises for the geographer in the construction of any map based on a sample, is the interpolation between sample values. On such a map only the points of observation as indicated by the sample are true to site; the interstitial spaces remain unknown and are interpreted by generalization.

(a) Geographical Phenomena

The geographical phenomena (variables) included in this model are cultivated land, grazing potential, relative relief, rainfall and temperature. Because physical factors apparently influence rural land use, while the converse is not true, cultivated land and grazing potential are regarded as the dependent variables and the physical factors (relative relief, rainfall and temperature) as the independent variables. *

The hypothesis to be tested is that there are significant mutual and associative relationships between cultivated land (y_1), and grazing potential (y_2), on the one hand and relative relief (x_1), rainfall (x_2), and temperature (x_3) on the other. The model used measures the validity of this hypothesis. The results of this analysis will enable the research worker to delimit regions of minimum deviation and should be recognised as the final stage of the analysis, prior to interpretation.

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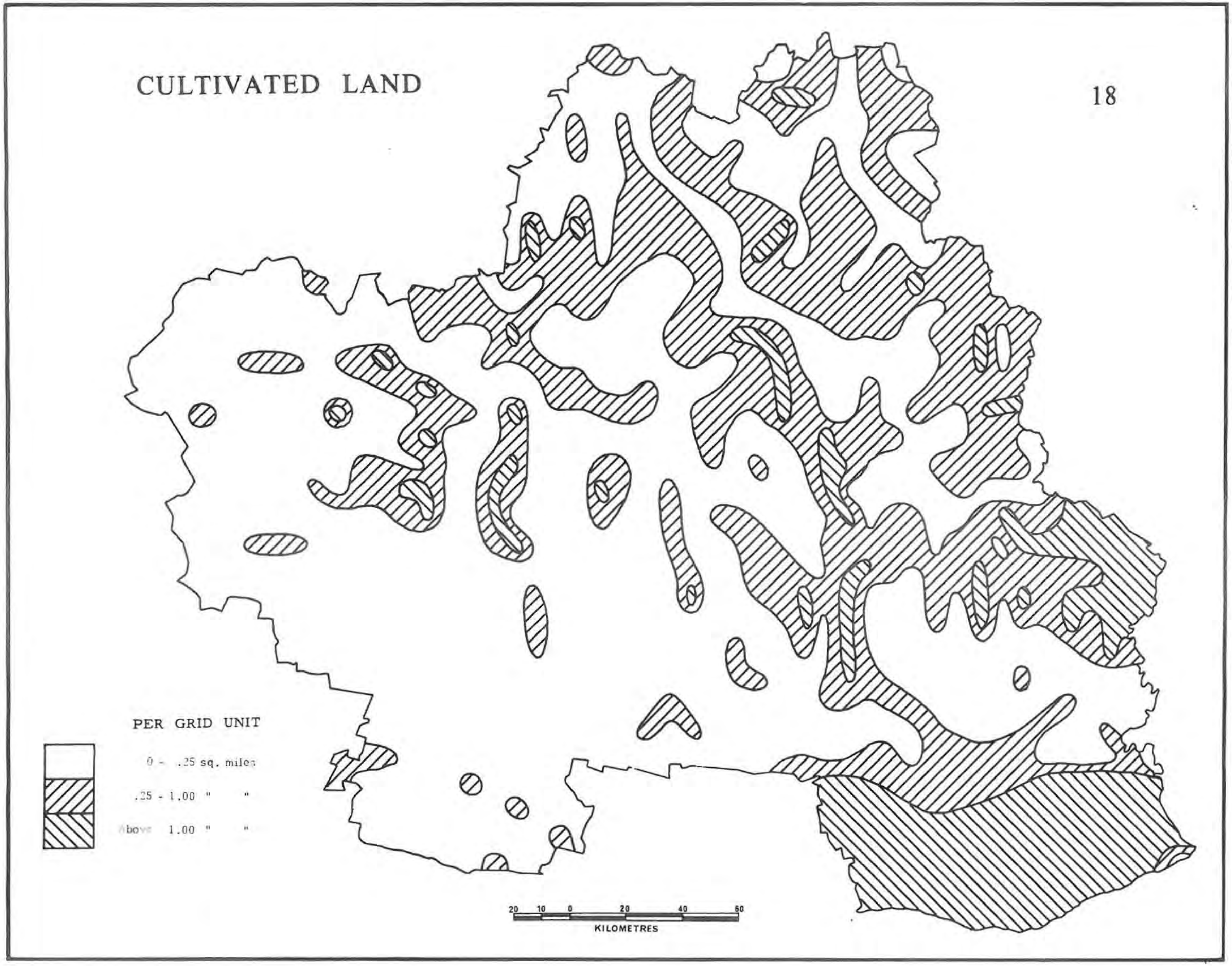
* The individual values of each variable were calculated in the following manner:

The area of cultivated land (y_1) in each grid square was measured from the land use map.

The grazing potential value (y_2) for each soil conservation district was plotted at the centre of the district and isopleths were interpolated to obtain intermediate values for each grid square.

The relative relief values (x_1) represent the difference in height between the highest and lowest contours in each grid square, and were calculated from the 1:250,000 topo-cadastral maps.

Rainfall (x_2) and temperature (x_3) were plotted for all available stations in or near the research area; isohyets and isotherms were drawn to give interpolated values for each grid square.


CULTIVATED LAND
18
PER GRID UNIT
0 - .25 sq. miles
.25 - 1.00 " "
Above 1.00 " "
20 10 0 20 40 60
KILOMETRES

GRAZING POTENTIAL

19

i. Dependent Geographical Phenomena

Cultivated land (y_1) is shown on the land use map (end pocket), and this distribution is discussed on pp. 93-8.

It is important for quantitative analysis, or the construction of models, that the maps, to be compared with each other, shall be compiled according to the same technique. The land use map, on which the cultivated land is symbolised by dots consequently had to be reduced to an isoline map based upon the proportion of the area under cultivation in each observation unit (Map 18).

The isoline values used were selected by the frequency graph method.[83] When constructing the frequency graph for cultivated land, the number of occurrences was plotted on the ordinate (y-axis) and the various surface area units on the abscissa (x-axis). Significant depressions (breaks) in the occurrences of densities, are used for isoline boundaries. In this way, the maximum number of homogeneous areal groupings is defined. This same method, viz. the determination of isolines, was used in the construction of the regions of minimum deviation.

In the whole research area, the arithmetic mean of cultivated land was computed* to be 0. 54344 square miles per grid unit. The standard deviation of 1. 01721 square miles is unusually high. This reflects the fact that the research area has large portions where no cultivated land occurs, whilst in other areas one finds a marked concentration.

Grazing potential (y_2) is the theoretical carrying capacity of the pasturage. In the abscence of detailed figures for livestock numbers, it is the best measure available of the pastoral element of farming in the research area.

There are no grazing potential data for individual farms available so the construction of Map 19 has been based on the average grazing potential for each of the 80 soil conservation districts in the research area. Theoretical carrying capacity for every district was stipulated in the Soil Conservation Act of 1946. Since then many of these values have been altered and the districts of soil conservation reclassified. With the co-operation of Dr. van Wyk of the Grootfontein Agricultural College, and Mr. Walters of the Department of Agricultural and Technical Services of the Eastern Cape

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83. Alexander, J. W. and Zahorchak, G. A., "Population-Density Maps of the United States", Geographical Review, Vol. 33, 1943.

* The computation was carried out on the IBM 1130 computer at Rand Afrikaans University.

Province area, Map 19 (grazing potential) was compiled. All data was converted to small stock units (S. S. U.)* as this area is used predominantly for sheep farming.

Over the whole research area, there is a definite decline, from east to west, in grazing potential. In the Bathurst magisterial district the pasturage with the greatest carrying capacity is found to be 0.5 morgen ** per small stock unit. To the west it gradually declines to a minimum of 3 morgen per small stock unit. *** In the magisterial districts of Murraysburg and Aberdeen for example grazing potential has an arithmetic mean of 1.98149 morgen per small stock unit. The standard deviation of the grazing potential values is 0.68702 morgen per small stock unit. In comparison with cultivated land, the variation distribution (standard deviation) of grazing potential is considerably smaller.

ii. Independent Geographical Phenomena

Relative relief (x_1), rainfall (x_2) and temperature (x_3) are the independent geographical phenomena. They are cartographically symbolised on Maps 2a, 9 and 11 respectively. Values for the arithmetical averages and standard deviations, respectively, for the three independent variables are:

a)	Relative relief (x_1)	average	=	1,002.4 ft.
		st. dev.	=	763.7
b)	rainfall (x_2)	average	=	393.1 mm.
		st. dev.	=	153.3
c)	temperature (x_3)	average	=	16.8 °C
		st. dev.	=	1.1

The next step is to determine the single and combined influence of relative relief, rainfall, and temperature on on cultivated land and grazing potential by means of more sophisticated statistical techniques. ****

(b) Quantitative Analysis

McCarty and Salisbury[84] remark on the importance of map usage as follows: "The use of maps and particularly the comparison

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* The weights used are the units employed by the Department of Agriculture - p. 102.

** 1 morgen = 0.857 hectares.

*** The lower the numerical value, the better the area.

**** The programme used was from Scientific Subroutine Package (1130-CM-02X) "Multiple Linear Regression", p. 146, Lit. No. H 20 - 0252 - 3.

84 McCarty, H. H. and Salisbury, N. E., Visual Comparison of Isopleth Maps as a means of determining Correlations between spatially distributed Phenomena, Dept. of Geography, State University of Iowa, 1961, p. 1.

of maps showing different kinds of data for the same portion of the earth's surface, rightfully occupies a central position in geographic research." By comparing visually maps 18 and 19 with maps 20 and 21 respectively, similarities are discerned. The quantitative nature of the similarities cannot however, be assessed visually. In a comparison between maps 9 and 18, it is immediately evident that there is a positive areal relationship between high rainfall and a high concentration of cultivated land. This is only a qualitative observation. By using either single (2 phenomena) or multiple (more than 2 phenomena) correlation coefficients, * and treating the values for individual grid squares as individual occurrences in a sample population, quantitative areal relationships can be determined.

i. Spatial Relationships

The first stage of the quantitative analysis is the calculation of the single correlation coefficient. For the geographer this correlation coefficient has the following meaning: "there is a need to compare sets of data in terms of the extent to which a change in one is or is not reflected by a change in the other set. This necessarily implies that the individual items of the two sets of data co-exist either in time or space, such that the possibility of interrelated changes can be considered".[85] This enables the geographer to see his problem in its entirety and he can perceive the relationship between cultivated land or grazing potential and any one of the independent physical elements in the research area.

In Table 14 the linear correlation coefficients ($r_{y_1 x_1}$; $r_{y_1 x_2}$; $r_{y_1 x_3}$) show that cultivated land covaries areally only with rainfall and temperature. There is an areal covariation, however, between all three physical elements and grazing potential. Covariation means that a significant single relationship exists between either cultivated land or grazing potential and the physical correlates. The coefficients of determination can be ascertained by squaring the correlation coefficients and can thus be expressed as a percentage. The areal similarity between cultivated land and rainfall is 27.04% and that between grazing potential and rainfall 70.5%. These percentages are merely global figures refering to the whole research area. In specific areas or groups of grid units a 0% or 100% covariation between rainfall and cultivated land may for example, exist.

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* All correlation coefficients were tested at the 99 and 95 percent confidence level.

85 Gregory, S., Statistical Methods and the Geographer, Longmans, 1963, p. 167.

SINGLE SPATIAL RELATIONSHIPS

(Linear Correlation Coefficients).

$r_{y_1x_1} = -0.04078$ N. S.

$r_{y_1x_2} = 0.52820$ **

$r_{y_1x_3} = 0.10479$ **

$r_{y_2x_1} = -0.10475$ **

$r_{y_2x_2} = -0.84172$ **

$r_{y_2x_3} = -0.21868$ **

MULTIPLE SPATIAL RELATIONSHIPS

(Multiple Correlation Coefficients).

$R_{y_1 \cdot x_1x_2x_3} = 0.54344$ **

$R_{y_2 \cdot x_1x_2x_3} = 0.85455$ **

COMPOUND SPATIAL RELATIONSHIPS

(Multiple Correlation of Determination)

$R^2_{y_1 \cdot x_1x_2x_3} = 0.2952$

$R^2_{y_2 \cdot x_1x_2x_3} = 0.7225$

y_1 = Cultivated Land

y_2 = Grazing Potential

x_1 = Relative Relief

x_2 = Rainfall

x_3 = Temperature

N. S. = Not Significant

** = Highly Significant (99%)

TABLE 14: SPATIAL RELATIONSHIPS (r, R and R^2) FOR THE RESEARCH AREA.

The geographer, as mentioned previously, is not interested soley in separate or individual phenomena. Rather the joint and mutual influence and interaction between heterogeneous phenomena is stressed. The calculation of multiple correlation coefficients is, therefore, the next stage of the analysis. Coefficients of determination have already been discussed in the context of single cases. For the geographer they become more meaningful in the analysis of multiple correlation. The multiple coefficients of determination, for example, for cultivated land is $R^2_{y_1 \cdot x_1 x_2 x_3} = 29.52\%$. This means that 29.52% of the variation in cultivated land over the surface of the research area may be "explained" * by the direct influence of the physical elements (x_1, x_2 and x_3).

A disadvantage of the above analysis of areal relationships (single and multiple correlation analysis) is that only one numerical value is obtained for the total research area. No inter-regional variation is indicated by these coefficients of determination; they can, however, indicate intra-regional variation. The determination of the spatial association-relationships (by means of multiple linear regression analysis) overcomes this problem of inter-regional variation.

ii. Spatial Association Relationships

In this phase of the analysis the association relation between the phenomena (correlates y_1, y_2, and x_1, x_2, x_3) can be expressed as an equation (multiple linear regression)** and used as a norm by which every unit of observation is evaluated.

The equations of multiple linear regression (y_c)*** for the cultivated land (y_1) and grazing potential (y_2) with the independent physical correlates of relative relief (x_1), rainfall (x_2) and temperature (x_3) are:

$$y1_c = - 1.48017 - 0.0015x_1 + 0.00551x_2 + 0.04776x_3$$

$$y2_c = 4.97507 + 0.000x_1 - 0.00364x_2 - 0.09309x_3$$

These regression equations show the stochastic relation of

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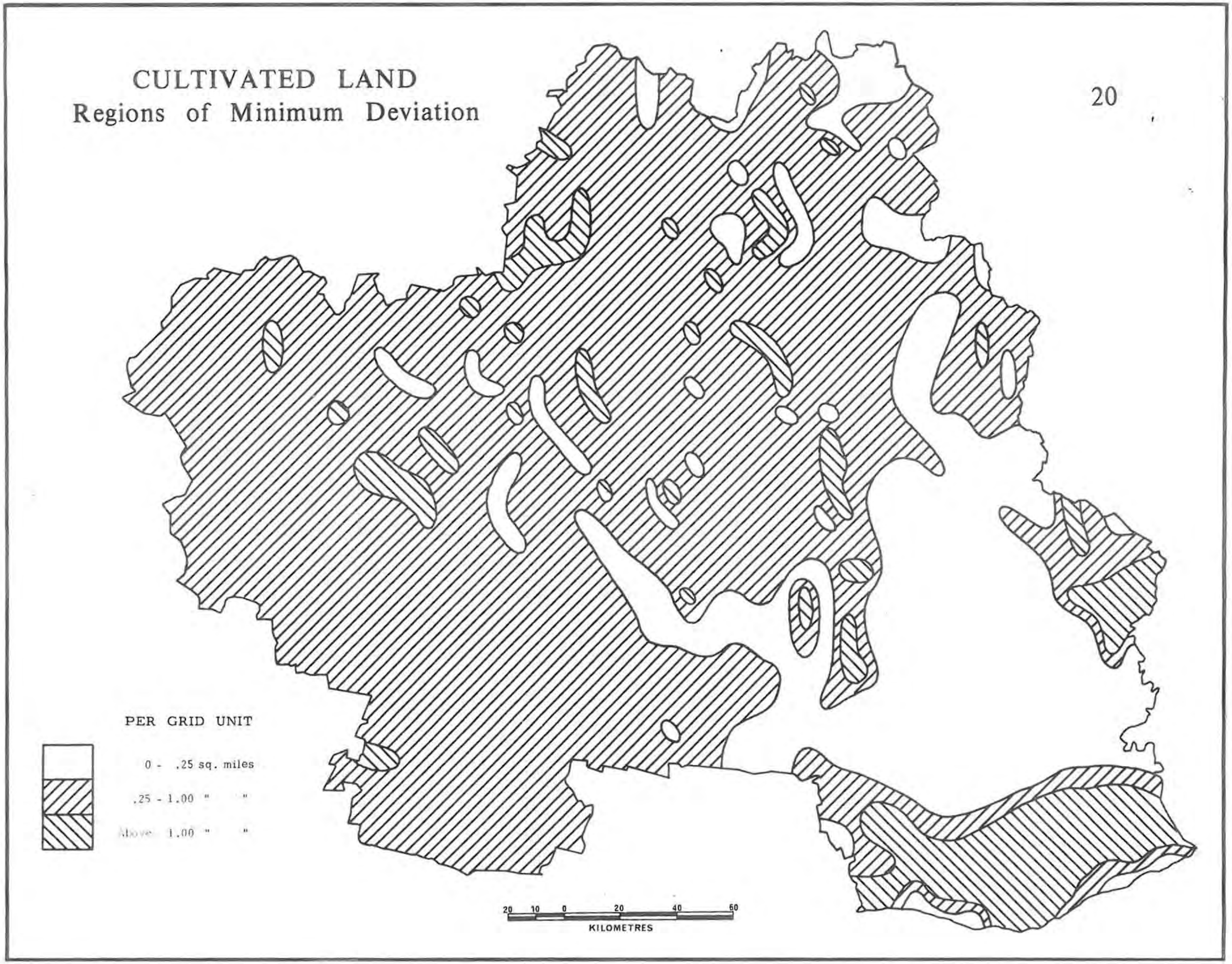
* The word "explained" is placed in quotation marks where it is used to signify "may be held to account for"; the relationship is statistical and does not necessarily imply a causal relationship.

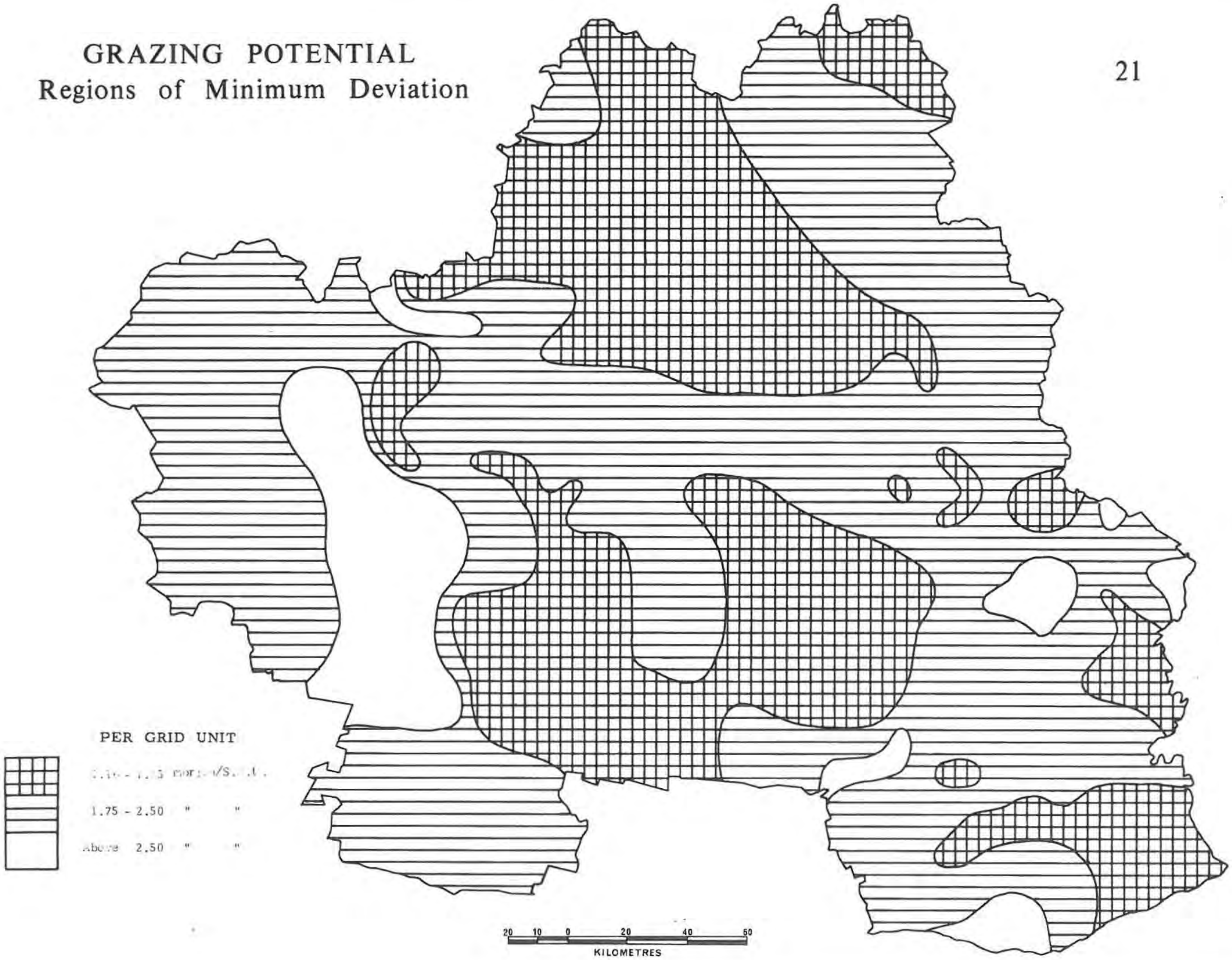
** In the regression analysis significance levels of 0.01 and 0.05 were written into the programme as the limits for acceptance of the data in the analysis of the matrix. The results of the F test on the coefficients of regression were also shown to be acceptable at the 99% confidence level.

*** c = calculate or estimate.


CULTIVATED LAND
Regions of Minimum Deviation
20
PER GRID UNIT
0 - .25 sq. miles
.25 - 1.00 " "
Above 1.00 " "
20 10 0 20 40 60
KILOMETRES

GRAZING POTENTIAL
Regions of Minimum Deviation

21



each of the dependent correlates (y_1, y_2) with the independent correlates (x_1, x_2 and x_3) for the entire research area. If the values of the three independent variables for a given grid unit are substituted in these equations an estimated value is obtained for each of the dependent variables for that grid unit.

Geographical research has shown that "the most promising type of maps for the presentation and analysis of statistical data is the so called map of residuals from regression".[86] A residual from regression is the difference between the observed value (y_1, y_2) and the calculated value (y_{1_c}, y_{2_c}) for each of the 1009 grid units. Should the observations of a correlate be described precisely by a multiple regression line, then there will be no difference between the ordinate and the regression line ($y - y_c = 0$). This would mean that the independent physical elements (x_1, x_2 and x_3) "explain" the dependent elements (y_1 and y_2) completely.

Before the spatial pattern of residuals can be compared directly with the spatial pattern of the original variable, the residuals have to be standardised and comparable class intervals selected. The residuals are standardised by adding the mean of cultivated land ($\bar{y}_1$) to each of the residuals for cultivated land ($y_1 - y_{1_c}$) and by adding the mean for grazing potential ($\bar{y}_2$) to each of the residuals for grazing potential ($y_2 - y_{2_c}$). The standardised residuals for cultivated land and grazing potential in each grid square are then mapped. On these maps regions of minimum deviation for cultivated land (Map 20) and for grazing potential (Map 21) are delimited. The same class intervals used on Maps 18 and 19 respectively are employed to give direct comparisons.

iii. Regions of Minimum Deviation (Maps 20 and 21)

The areal patterns of cultivated land and grazing potential are determined by a large number of heterogeneous phenomena. In most cases it is impossible to identify and isolate all these phenomena and their mutual relationships. Only the result of these factors can be observed directly in the cultural landscape. With regard to the research area, this result, viz. the actual distributions of cultivated land and of grazing potential values are cartographically symbolised on Maps 18 and 19, and discussed on pp. 74-96. The regions of minimum deviation (Maps 20 and 21), can be regarded as hypothetical situations showing the integrated result of cultivated land and grazing potential as influenced by the physical factors: relative relief, rainfall and temperature. The regions of minimum deviation can be used to interpret the extent to which the

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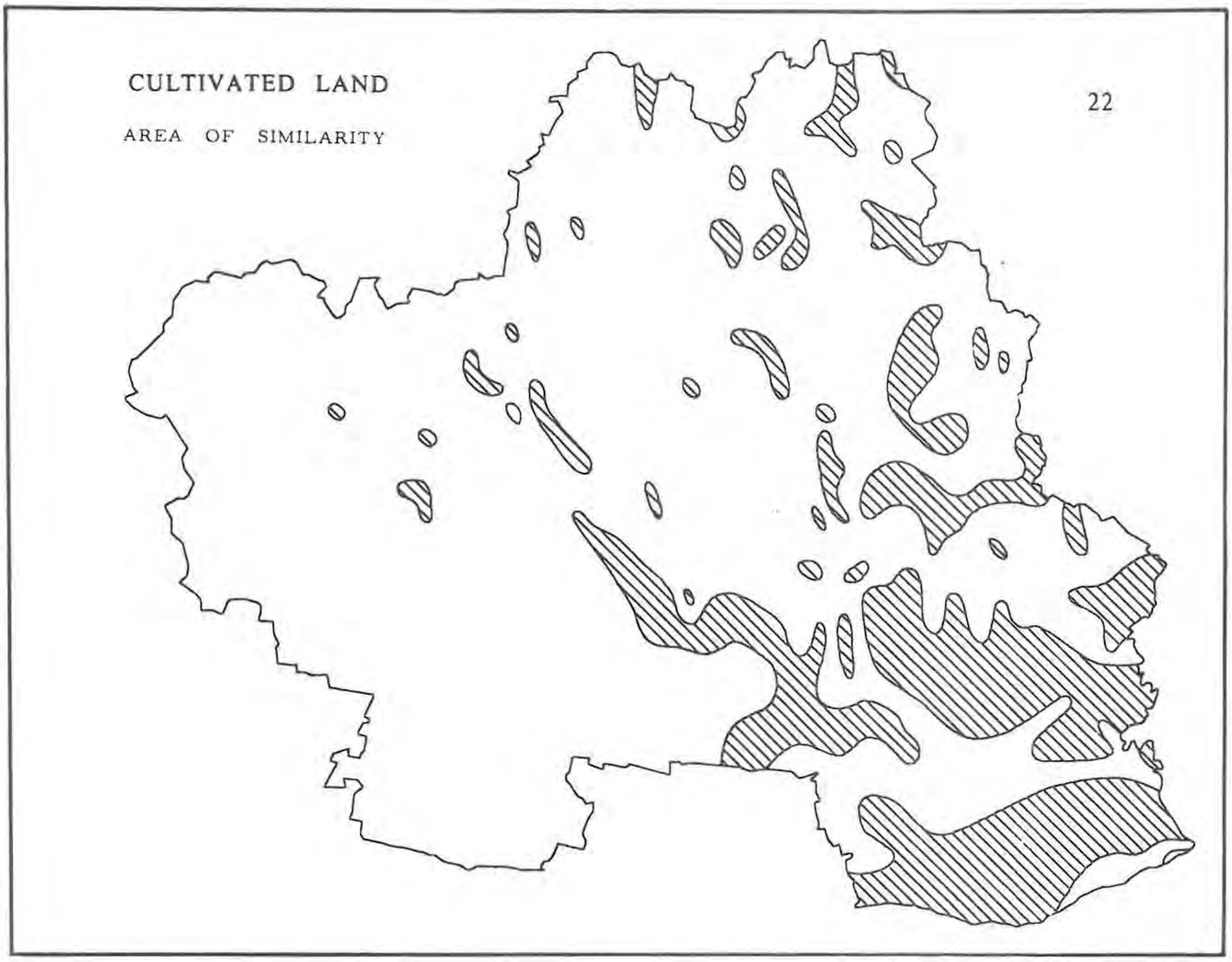
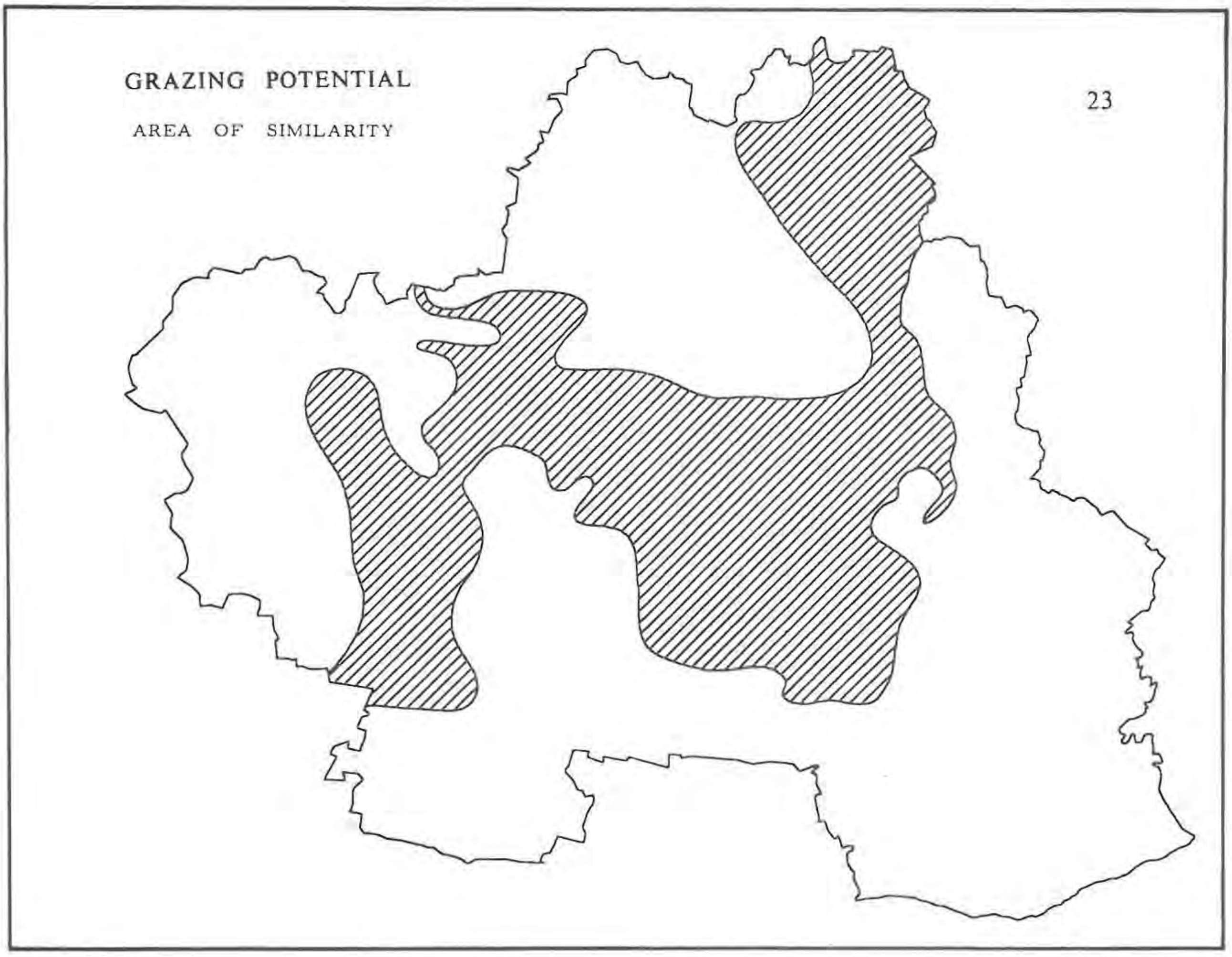
86. Thomas, E.N., "Maps of Residuals from Regression" in Berry, B.J.L., Marble, D.F., Spatial Analysis : A Reader in Statistical Geography, New Jersey, 1968, p. 326.


CULTIVATED LAND
AREA OF SIMILARITY
22


GRAZING POTENTIAL
AREA OF SIMILARITY
23

three physical correlates can "explain" the areal distribution of cultivated land and grazing potential.

Firstly, should the various equations of regression for cultivated land (y), and grazing potential (y_2) give, independently, zero residuals ($y_1 - y_{1_c} = 0$ and $y_2 - y_{2_c} = 0$) for each grid unit in the research area, it would mean that the physical correlates (x_1, x_2 and x_3) completely "explain" the areal pattern of rural land use. This would imply that the large number of unknown factors which were supposed to determine the distribution of cultivated land and grazing potential, have been reduced to three known factors (x_1, x_2 and x_3).

Secondly, should there be no similarity between the pairs of maps of actual and calculated values, it would mean that the three physical factors have no direct relation with the two dependent variables, viz. cultivated land and grazing potential. In this case the research worker would have to select other variables and start his analysis anew.

Thirdly, should there be a similarity between the maps only in certain areas, the distribution of cultivated land and grazing potential value would be partially "explained" by the three physical factors, and the research worker could repeat his analysis with the addition of more variables. Maps 22 and 23 show these areas of similarity where the two dependent phenomena (y_1 and y_2) are "explained" by the physical correlates (x_1, x_2, and x_3).

iv. Area of Similarity (Maps 22 and 23)

The area of similarity (overlap) on Map 22 (Cultivated land) can be explained by the following practical example. Let us compare the multiple regression equation with a pair of scales. In the one scale we have the value of cultivated land (y_1) and in the other scale a constant value (constant of regression) plus three independent values (x_1, x_2 and x_3). The area of similarity on Map 22 is where the scales are in equilibrium - there is neither too little nor too much cultivated land in terms of the three physical correlates per grid unit. These areas can be classified as normal. The areas outside the overlap qualify as above and below normal areas, i. e. areas where there is too much or too little cultivated land. The patchy distribution of areas of similarity suggest that the three chosen independent correlates do not on their own offer a satisfactory explanation for the distribution of cultivated land.

The same example, used for the interpretation of Map 22, can be used to explain Map 23 (Grazing Potential). The area of similarity, or the normal area, extends from the north eastern boundary in a flat S-shaped pattern up to the south western boundary of the research area. It covers the greater part of the following magisterial districts: Maraisburg, Steynsburg, Cradock, Somerset East, Pearston, Graaff-Reinet and Aberdeen. The values added for grazing potential (number of morgen per S. S. U.) within the area of overlap, are correct in terms of the three physical correlates (x_1, x_2 and x_3). The values added for the areas outside the overlap (morgen/S. S. U.) are too small or too large, i. e. above or below normal. To determine the correct quantitative value (morgen/S. S. U.) for these areas, it would be necessary to substitute new added values (larger or smaller) for grazing potential and calculate new residuals per grid unit. This implies that the class interval boundaries on Map 21 would shift, which would result in a greater overlap on Map 23.

Where the maps differ from each other, the difference must be ascribed to other factors and not only the physical factors here used. To explain these areas where the maps differ from each other, it will be necessary to determine new variables. Some of the most important factors, which influence rural land use in the research area, and which could be used as independent variables are; size of the farms, farm planning, water resources, soil types, and economic factors.

For this particular research, the application of a grid model was the most suitable method for delimiting cultivated land and grazing potential, with three physical phenomena as criteria, in "explained" and "unexplained" areas. Furthermore, this model enables the research worker to determine exactly to which areas he should limit his future research.

C. SUMMARY AND CONCLUSIONS

With the arrival of European and Bantu settlers in the 18th century both grazing and cultivation increased rapidly. What was primarily a natural landscape, now took on the features of a cultural landscape, with characteristic patterns. Agriculture, as an important component of the cultural landscape, gradually increased in extent and intensity. New requirements, in which a water supply is the most important factor, originated as a result of this.

Initial success in the application of flood irrigation gave rise to intensified land use. At a later stage, storage dams were built; these, however, silted up gradually and caused a shortage of irrigation water. This shortage affected the irrigation areas along the Sundays and Fish Rivers severely. In the rest of the research area, selective grazing and over-grazing had far reaching results; the most important of these was the swift deterioration of the natural vegetation and soil erosion. Water shortage is no longer the only threat to land use. The whole structure of the carrying capacity of livestock has changed. Not only an extra water supply, but also soil and veld conservation can be emphasized as the most important requirements to improve farming.

It is doubtful whether recovery measures can ever restore the natural balance in the research area with its predominantly semi-arid character. Whilst man is trying to restore the disturbed balance of the natural pattern, he is, at the same time, busy intensifying the cultural pattern, which, in actual fact, is responsible for this disturbance. The farmer must maintain a careful alliance with the processes of nature: as a prerequisite he must understand these processes, and he must organise his farming system in such a way that it is in harmony with the natural environment. It is unfortunate that in some areas, economic incentives have encouraged the farmers to flout this principle, dangerous though that may be. Different malpractices have arisen, of which over-grazing is one of the most important.

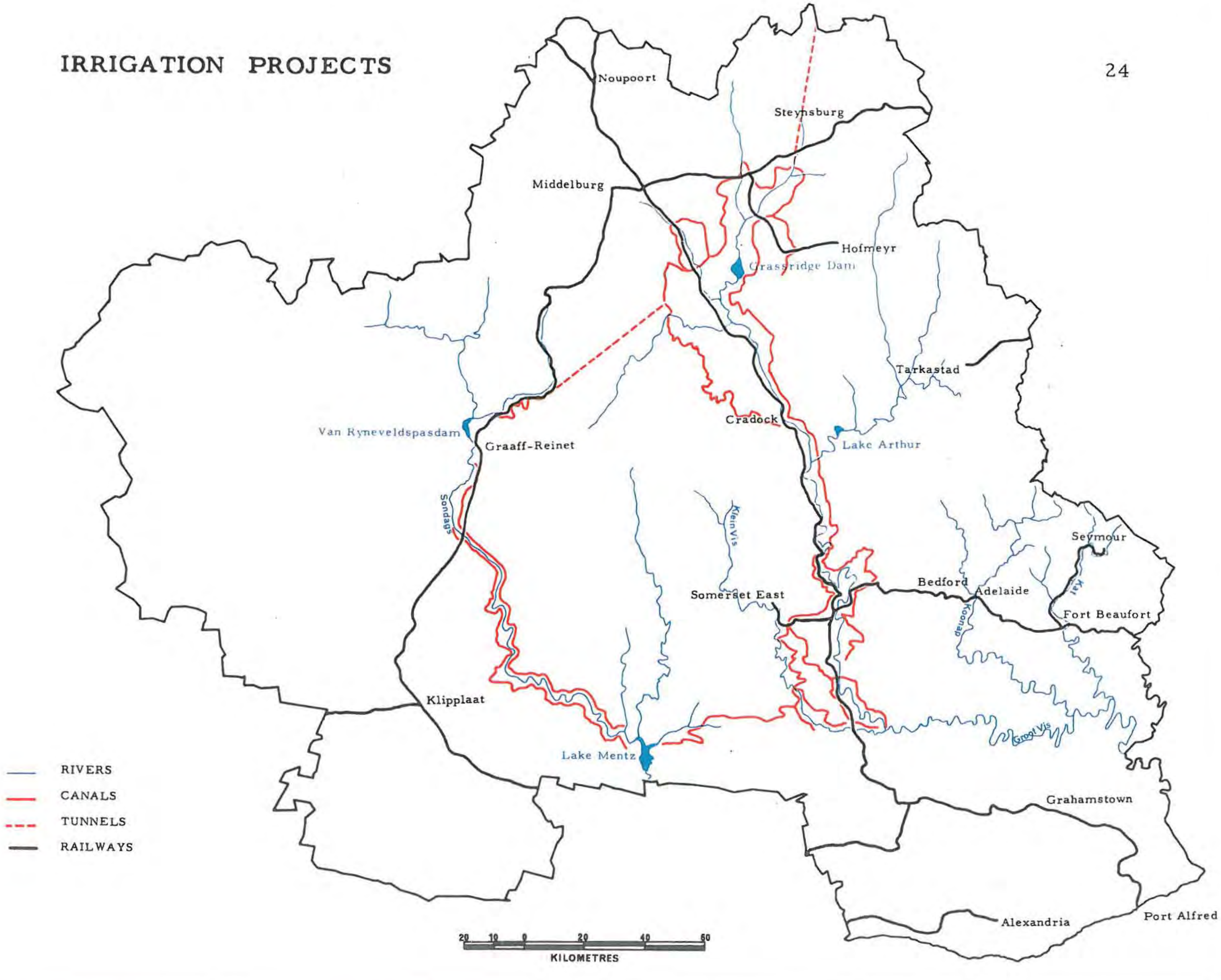
The solution to the water shortage problem does not lie within the research area. After completion of the O. R. P., the evolution of agricultural land use, mainly along the Sundays and Fish Rivers, will correlate highly with abundant and reliable water supply from the Orange River. Of paramount importance is the question: how is this water to be utilized? According to official reports, the ultimate aim is to develop the extensive irrigation areas along the Sundays and Fish Rivers into intensive irrigation schemes. Does the answer to the above question lie in the development of these small intensive irrigation schemes, where the emphasis falls mainly on the production of cash crops, or should this water rather be utilized by existing farming units along the Fish and Sundays Rivers. In the latter case, the cultivation of fodder crops will be the main objective. This additional fodder could enable the farmer to overcome one of the biggest hazards at present, namely, over-grazing.

In the predominant agricultural regions of South Africa the Gross Geographical Production (G. G. P.) per capita is generally lower than the average for the whole country. During the period 1959/60, the average G. G. P. per capita for the country was R298, whilst the G. G. P. per capita in the research area, which partially consists of three economic regions, varied between R18 and R289. This tendency can largely be ascribed to the fact that agricultural production, because of its sensitivity to climatological changes, is less stable. The more diverse the economic activity in a specific area or region, the more rapidly will such an area or region tend to develop, measured in terms of G. G. P. per capita and the less sensitive will it be to adversities in the agricultural sector. Whilst the development in the research area will be mainly agriculturally orientated, it is to be expected that industries, based on agriculture, will follow. These industries will have the effect of bringing about a more diversified economic structure, but will not necessarily eliminate the fluctuations, because the raw materials will be obtained largely from agriculture.

The extent of these future changes can be determined with the aid of the matrix model. This model, despite certain previously mentioned disadvantages, is most suitable for the assimilation of statistical data. By comparing future crop and livestock combinations maps with Maps 16 and 17 the change in the pattern of farming per magisterial district could be determined. For geographical regional research, the grid model can be recommended. It enables the research worker to compare maps accurately and it is a norm of great reliability, by which integrated regions can be delimited. Furthermore, this model evinces great potential which further research could exploit.

APPENDIX

IRRIGATION PROJECTS



APPENDIX

A. THE ORANGE RIVER PROJECT AND EXISTING SCHEMES

1. Introduction

As early as 1842, the pioneer John Centlivres Chase saw the future development of South Africa in terms of the natural resources of the country and he described the Orange River thus: "If this river were diverted from its course, which doubtless might be effected by a good engineer, its waters could irrigate thousands of acres of the richest kind, and afford food for an immense population".[1] More than a hundred years had to go by before these words were realized with the beginning of the Orange River Project.

The possibility of diverting water by means of a tunnel from the Orange River to the Great Fish River valley was first mentioned in 1928 by Dr A. D. Lewis, who was the Director of Water Affairs at that time. In 1944 the necessary field-surveys were begun and in 1948 the technical report was presented. During 1947 test drilling was started and by 1953 the initial surveying and investigation was largely completed. After a temporary pause, the investigatory work was continued in 1959. It reached a climax in 1962-63 when the official report concerning the proposed Orange River Development Project made an appearance.[2]

2. The Orange River

The Orange River has its source in the Drakensberg within the eastern boundary of Lesotho, and with its tributaries drains the highland west of the Drakensberg watershed. It flows westward over a distance of 2100 kilometres, through areas of progressively greater aridity, to enter the Atlantic ocean.

The Orange River has a catchment area of 849, 520 sq. kilometres and a mean annual run-off of 11, 226, 000, 000 kilolitres at its mouth. Only the 292, 670 sq. kilometres of the combined catchment of the Vaal and Upper Orange, lying upstream of their confluence, contributes appreciably to the run-off, i. e. 11, 022, 000, 000 kilolitres per annum. All the water of the Vaal River is required for use within its own catchment, leaving 6, 584, 000, 000 kilolitres per year, derived from the Upper Orange and its tributries upstream from the Vaal-Orange confluence. After the necessary deductions have been made concerning the consumptive use in the upper region of the Orange River and the amount which will be diverted to the rivers of the Orange Free State, the quantity which is available for the Orange River Development Project amounts to 5, 540, 000, 000 kilolitres.

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1. Bowker, T. B., "Claiming the Bounty of the Orange River", Optima, March 1963, p. 27
2. Report on the proposed Orange River Development Project, W. P. X. - '62, p. 3

By providing sufficient storage it is possible to utilize 75% of the latter quantity. On the average 1,363,000,000 kilolitres per year will be lost in the form of unavoidable evaporation losses and losses over the spillways of the storage dams during high floods. A reasonably assured supply of 4,177,000,000 kilolitres per year will remain for beneficial use.

The silt of the Orange, as determined by means of samplings over long periods, amounts to 0.8 per cent of the run-off. The practise of intensive soil conservation measures and improved agricultural techniques in that portion of the catchment area which falls within the Republic, will largely reduce the future silt load. The remainder of the silt load will be combated by the provision of outlet gates in the dams near the foundation level and by carrying out raisings of the dams later in order to restore the capacity lost.

The Orange River is known for its high floods. On 24th March, 1925, a flood of 9,000 cu. metres per second occurred in the Orange at Hopetown. A flood of 11,300 cu. metres per second took place at the same point in February, 1874. In the design of the dams on the Upper Orange River provision will be made to pass floods with a peak intensity of 16,900 cu. metres per second. The dams themselves will be designed to be safe even against floods of 22,600 cubic metres per second.[3]

3. Description of the Construction work within the Research Area

(a) The Orange - Fish Tunnel

The Orange - Fish Tunnel forms the key structure that will effect the deliverv of water from the Orange River to the Fish- and Sundays River valleys. After completion, it will rank as one of the longest tunnels in the world, i.e. 83 kilometres, with a fall of 1 in 2,000 and an internal diameter of 5 metres.[4]

The tunnel inlet is situated 42 kilometres upstream of the wall of the H. F. Verwoerd Dam, at a point where the reduced level of the river bed is at a height of 1,219 metres. The inlet at the entrance to the tunnel will be at a point where the reduced level is at a height of 1,228 metres. The capacity of the tunnel when operating under free flow conditions, will be 34 cubic metres per second.

In the initial stages of the development project the tunnel will discharge all its water into the Theebus Spruit, near Steynsburg, whence it will flow into Grassridge Dam. This latter will serve as a regulating dam for the areas to be served along the Fish River and the Lower Sundays River. A control tower will be constructed at the entrance of the tunnel. This control tower will house the gates which regulate the flow of water into the tunnel. The outlet of the tunnel will also be provided with regulating gates which will make it possible to generate hydro-electric power.[5]

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3. Ibid., p. 4
4. Ibid., p. 12
5. Ibid., p. 33

(b) The Klipfontein - Lake Mentz Canal

This proposed canal will begin at the Klipfontein weir in the Fish River. The initial capacity will be 10 cubic metres per second, which later can be increased to 17 cubic metres per second by lining the canal with concrete. The canal will extend over a distance of 74 kilometres to a point south of the town of Somerset East, where it will enter a short tunnel, to discharge its water into the Little Fish River. The capacity of this canal will be increased during the second phase of the development plan, when an area in the Lower Fish River, in the vicinity of Cookhouse, will be developed. From a point lower down in the Little Fish River a canal with an ultimate capacity of 10 cubic metres per second will be built over a distance of 29 kilometres to a point on the watershed at Beenleegte. Here the canal will discharge its water into an upper tributary of the Skoenmakers River, whence it will flow into Lake Mentz.[6]

(c) Conway Canal and Wapadsberg Tunnel

i. Conway Canal

The Conway Canal will begin at the outlet of the Orange - Fish tunnel and will stretch southwards on the western side of the Fish River. The main canal will continue up to the portal of the Wapadsberg tunnel, at a distance of 138 kilometres from the start of the canal. At this point a branch canal with a length of 40 kilometres will take off and follow along the right bank of the Great Fish River. The Conway main canal, together with its branches, will serve 21,400 hectares in the Fish River catchment and will in addition supply 7.1 cubic metres per second to the Upper Sundays River valley through the Wapadsberg tunnel.

ii. The Wapadsberg Tunnel

This tunnel will have a length of 52 kilometres and an internal diameter of 2.5 metres. The inlet will be at a reduced level of 1,134 metres. The fall will be 1 in 1,000 and the capacity 7.1 cubic metres per second. The tunnel will have its outlet in the Sundays River valley from where the water will flow to the Van Rynevelds Pass Dam. The latter will be used as a balancing unit and will serve existing and new irrigation areas between Van Rynevelds Pass Dam and Lake Mentz. Canals, as shown on Map 18 , on both banks of the river will transport the water.[7]

(d) The Hofmeyr Canal

Like the Conway Canal, the Hofmeyr Canal will also take off from the Orange - Fish tunnel and will stretch southwards along the eastern bank of the Great Fish River over a distance of 74 kilometres. It will

6. Ibid., p. 34
7. Ibid., p. 13

serve 12,900 hectares extending as far as Grassridge Dam.[8]

According to the official report, the Orange - Fish Tunnel and Klipfontein - Lake Mentz Canal will be completed during phase No. 1. Construction phase No. 2 includes the enlargement of the Klipfontein Main canal. Phase No. 3 includes mainly the construction of the Conway Canal, the Wapadsberg tunnel and the construction of a main canal - and distribution canal system for new irrigation in the Jansenville area. The Hofmeyr Canal and the distribution canal system for the Conway area are included in Phase No. 4.[9]

4. Available Irrigable Land in the Research Area

From a total of at least 308,340 hectares of irrigable land which can be taken into consideration for irrigation under the O. R. P., nearly 30% i.e. 96,780 hectares, are situated outside the Orange River watershed and exclusively within the research area, except for the existing and future development in the Lower Sundays River.

(a) Fish River Valley

At present 18,840 hectares fall under the irrigation development in the Great Fish River valley. Of this 11,130 hectares will have to be taken over by the O. R. P., because local water resources are only sufficient for 7,700 hectares.

As a result of extensive soil surveys of new irrigable land, it was determined that 55,670 hectares of new land could be considered for irrigation in the Fish River Valley.

(b) The Sundays River Valley

As a result of the insufficient water supplies from the Van Rynevelds Pass Dam, 7,700 hectares of the initial 18,840 hectares have at present been scheduled for irrigation, whilst the local water supply is sufficient only for 2,570 hectares. As soon as water from the Orange River can be made available at a later date, this de-scheduled ground in addition to 8,565 hectares of new ground, which can be served, can be made productive again.[10]

5. Water requirements within the Fish-Sundays River Sector

(a) Irrigation

In the Fish and Sundays River valleys the average water requirements of crops under irrigation, including canal losses, can be put at 790 mm. per year, measured at the tunnel outlet. This favourable figure is due partly to the lower consumptive use in these valleys and partly to the fact

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8. Ibid., p. 14
9. Ibid., pp. 14-16
10. Ibid., p. 1

that a portion of the new development area is situated in the Upper Fish River valley, within a short distance of the tunnel outlet, with consequent reduced canal losses. The total quantity of water which will have to be diverted from the Orange River to serve the 96,780 hectares of development amounts to 1,005,000,000 kilolitres per year, of which 671,000,000 kilolitres will be required for existing and future development in the Great Fish River valley.

(b) Urban and Industrial Water Supply

Specific water allocations for urban and industrial use are proposed for certain towns and villages, with the clear understanding, however, that the afore-mentioned allocations can be increased in the future as required by circumstances. On the basis of this understanding, it is proposed to make the preliminary provision that from a total of 455 m.l.d., towns along the Fish River will receive 64 m.l.d. and towns along the Upper Sundays River will receive 45 m.l.d.[11]

6. Aims and Advantages of the Orange River Project (O. R. P.)

The first aim of the O. R. P. is to increase the agricultural production by nearly R114 m. per year after completion of the first phase.[12] To realize this aim, approximately 9,000 new farms will have to be created.[13] One of the most important contributions of the O. R. P. is that it will avert the destruction of existing irrigation schemes amongst which are those in the Sundays and Fish River valleys. In the past R200,000,000 has already been spent on the development in the valleys of the Sundays and Fish Rivers and this is endangered by the present water shortage. In this way R50,000,000 has been spent on the establishment of citrus groves in the Sundays River. Of these, thousands of trees have already been lost and the citrus export has been decreased by 50%.[14]

In the Upper Fish and Upper Sundays River valleys the dry climate in winter and early summer lends itself to the cultivation of wheat under irrigation. Wheat growing requires a low water quota and can be considerably expanded. The gross value of agricultural production under irrigation is estimated at R350 per hectare per year.

The importance of these areas lies not only in the increased agricultural production for internal consumption, but also in their ability to earn foreign exchange. Thus, additional water supplies will stabilize the production of fruit and citrus for export in the Lower Fish River valley and will increase the production of the staple product, wheat, in the Upper Fish and Upper Sundays River valleys.

The greatest part of the research area lies within the most important wool producing area in the Republic. The wool industry is periodically

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11. Ibid., p. 7
12. Die Huisgenoot, 23 Mei, 1969, p. 12
13. Financial Mail, Special Survey, April 1969, p. 13
14. Bowker, T. B., op. cit., p. 28

subjected to drought and this can largely be improved by the future stabilizing and promotion of primary fodder crops. It is calculated that the lucerne and maize that will ultimately be produced under the project will be sufficient as grazing for 18 m. sheep during winter and especially in times of drought. This, in turn, will increase the production of wool by approximately 16,300 metric tons per year and bring about a 20 per cent increase in lamb production.[15] Not only will the wool and lamb production benefit by the project, but a potential increase in meat and milk production can be expected. The increased production of beef and mutton will serve to provide on a long-term basis for the needs of the increasing population and for the rising standards of living of the people.

Whilst the main aim of the O. R. P. is to supply water for agriculture, the industries might eventually become the chief receivers. It is imperative that the emphasis should change; as the population increase in South Africa somewhat exceeds 2% per year, additional possibilities for work have to be established for more than 400,000 people per year. Eventually the primary industries like agriculture and mining will provide work for an ever decreasing percentage of the population. The secondary industries (mainly the basic iron and steel industries and chemical industry) and the industries which provide employment will have to be depended upon to bridge this gap.[16]

7. Hydro-Electric Power

Although hydro-electric power is generated only as a by-product of the O. R. P., it will nevertheless play an important role in the future development of the research area, especially the valleys of the Sundays and Fish Rivers. From a grand total of 20 stations, 10 hydro-electric power stations under the control of the Electricity Supply Commission are planned for the Fish and Sundays River sectors. After completion the total continuous power rating of these 10 stations should be 87.0 megawatts.

On the Fish-Sundays River sector, the fall at the Orange- Fish tunnel, in addition to the various falls in the canal system, will be utilized for the development of hydro-electric power.[17]

B MINOR SCHEMES

1. The Kat and Koonap Rivers

As tributaries of the Great Fish River, these two rivers drain the eastern sector of the Second Escarpment. They rise on the southern slopes of the Winterberg and run southwards over a distance of approximately 200 kilometres. Here they flow into the Lower Fish River.

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15. Financial Mail, op. cit., p. 13
16. The Standard Bank Review, "The Progress of the O. R. P.", August 1968, p. 4
17. Report on the proposed O. R. P., W. P. X - '62 pp. 22-24

The rainfall along the length of these rivers varies from 250 to 1,300 mm. per annum. Their flow varies from a maximum during February/April to a minimum during July/August. Spring and early summer rains are very unreliable, and when they fail, the flow of the rivers stops entirely along most of their course. The upper reaches of the rivers, adjacent to the mountains, still enjoy a fairly permanent flow and water supplies are more or less adequate in normal years, but definite shortage may be experienced even here in times of drought.

(a) Irrigation Construction work within the Kat and Koonap Valleys

After investigation, a dam site in the Kat River was selected a few miles downstream from Seymour. Excavations for the dam wall commenced in April, 1964. The wall itself, scheduled for completion at the end of 1969, will be 425 metres long and rise 55 metres above the bed of the river. With a catchment area of 245 sq. kilometres the resulting dam will hold approximately 24, 660, 000 kilolitres of water. This dam will stabilise the flow of the Kat River and provide an assured supply of irrigation water for the citrus orchards and irrigable fields downstream. The area scheduled for irrigation is 1, 400 hectares.

The Koonap, as one of the main rivers of the Eastern Cape, is in fact the largest underdeveloped river in this area. The most important privately owned dam on the river is situated 50 kilometres north of Adelaide, and three farmers lower down the river are already buying water from the dam-owner to augment their supplies.

Numerous dam sites have been investigated by the Department of Water Affairs. At least eight sites have been surveyed, and in some cases test drilling for foundations has been carried out. In 1962 it was reported that a combination of three dams would develop the full potential of the Koonap River. Three such suitably placed sites exist, namely at Skurwekop (50 kilometres north of Adelaide), Foxwood (5 kilometres north of Adelaide) and Leeuwdrift (50 kilometres south of Adelaide). To serve the irrigation requirements as well as the requirements of Adelaide, Foxwood seems to be the most suitable site. A dam here with a capacity of 66, 580, 000 kilolitres would irrigate approximately 2, 300 hectares of land. This dam would be big enough to serve all irrigators as far as the Fish River. The water requirements of irrigators above Foxwood will have to be provided by a dam at either Waterfall or Skurwekop.

(b) Agricultural Activities and Potential

A fair amount of citrus is grown in the valleys for export. In the Koonap valley the total annual commercial crop is about 100, 000 cases. An analysis of the cost structure for all the various citrus growing areas of the Republic, conducted by the Citrus Exchange in 1966, showed that for any given production per tree, the Eastern Cape Midlands area has the highest cash return per tree. In spite of this, farmers (especially some small farmers in the Kat River valley) lack confidence in the constant profitability of citrus. Where the production of the citrus orchards has declined because of the age of the trees, the orchards are in many instances not replaced. In some instances citrus trees have been replaced by either lucerne or other perennial crops irrespective of their economic yield.[18]

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18. Information obtained from the Extension Officer, Fort Beaufort

Tobacco is cultivated in the upper parts of the Kat River valley, where it is the main source of income for the small farmers. A few farmers have been successful in the cultivation of flue-cured tobacco, whilst others are considering the possibility of switching over to this system.

Lucerne and other fodder crops for winter feeding are cultivated in both river valleys. In the lower reaches lucerne is virtually the only crop as it is capable of withstanding prolonged periods of drought and responds quickly to heavy irrigation from flood flow.

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