

THE NATURAL VEGETATION OF THE ROBERTSON
KAROO: AN EVALUATION OF ITS CONSERVATION
STATUS

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ABSTRACT

The natural vegetation of the Robertson Karoo contains many taxa and vegetation communities worthy of conservation. This thesis is concerned with aiding the future conservation of natural vegetation of the Robertson Karoo by assessing the threats to its survival and identifying priority conservation areas.

The history of the Robertson Karoo environment from 20 000 years BP was assessed, while the changes over the last 50 years were evaluated in more depth. Trends in the land use patterns were assessed by choosing seven representative areas as "case studies". The land uses of these areas were mapped from 1942 to 1987 using aerial photographs. General patterns of vegetation change for the whole area were calculated from 1:50 000 maps from the year 1960 to 1987. Results show that the natural vegetation, predominantly Karroid Broken Veld, has been reduced on average by 0.7% of the total study area per annum. By 1987, 34% of the natural vegetation had been cleared, primarily as a result of agricultural expansion.

Although results suggest that large scale agricultural expansion is unlikely in the near future, agricultural development still represents the greatest threat to the future well-being of the natural vegetation of the Robertson Karoo. Urbanization and mining were also found to be significant, albeit minimal, threats to the remnant vegetation. Alien infestations are only severe along the Breede River and in the vicinity of Brandvlei Dam.

Agricultural threat indices (probability of clearance for agriculture) were derived for the whole region through quantitative assessment of critical agricultural criteria, viz soil quality, slope gradient and precipitation. These indices were found to correlate with previous clearance of vegetation for agriculture. They are, therefore, of value for predicting future vegetation clearance. It was also found that the greater the distance from a river, the primary source of irrigation water, the less the likelihood of future agricultural development.

Many rare and/or threatened habitats, especially the transitional zones and the river gravels, are not conserved. Just over a 1/6th of the 61 threatened plant taxa occurring in the Robertson Karoo are conserved within existing reserves. It appears that the conservation of homogeneous stands of Broken Karroid Veld and the conservation of large mammals have been overemphasized, ignoring the localized habitats containing rare and/or threatened plant taxa. Priority conservation areas were identified using two equally weighted criteria: a) number of the threatened taxa occurring in the area and b) the degree of human threat. It is of vital importance to conserve at least a proportion of these priority areas in a network of reserves ranging from 0.05km² to 5km². An important conservation strategy in this region is persuading decision-makers, primarily private landowners, to conserve the natural vegetation.

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NOTE

For the purposes of publication the 1:250 000 maps used in this thesis were photographically reduced to fit onto an A4 page. The original 1:250 000 maps are housed at the Karoo Botanic Gardens, Worcester.

CHAPTER 1: INTRODUCTION

The World Conservation Strategy (IUCN 1980, Chapter 1) defined conservation as the "management of human use of the biosphere so that it may yield the greatest sustainable benefit to present generations, while maintaining the potential to meet the needs and aspirations of future generations". This definition includes protection, preservation, restoration, enhancement and sustainable use of ecosystems as well as the provision of a fit habitat for humanity. However, for the purposes of this thesis, the term "conservation" is used simply to describe policies and programmes necessary for the long-term retention of natural communities under conditions which provide the potential for continuing evolution.

1.1 WHY CONSERVE?

The philosophy and rationale for the conservation of natural ecosystems is complex and has been a subject of considerable debate. The following points outline the values (all anthropocentric) of natural ecosystems which justify their conservation:

a) Recreational and aesthetic values

Natural ecosystems have an inherent "beauty" worthy of retention for the benefit of present and future generations of human beings. Extremists contend that the opportunity to enjoy nature, at least on occasion, is a prerequisite for sound mental and physical health (Iltis *et al.* 1970). In addition, a large proportion of natural communities are economically viable because they are a basis for many recreational and tourist

activities.

b) Religious values

Judaeo-Christian religions emphasize the morality concerned with the sanctity of natural ecosystems, whereas certain Eastern religions stress the divine rights of "non-human beings". Humans may either be seen as the responsible "custodians" of "lesser species/organisms", or as equals, where it is of vital importance for co-created biota to have a continued and and harmonious co-existence with humankind (McDowell 1988).

c) Cultural values

Natural communities form part of the historical environment which is closely tied with the development of civilization. Hence natural communities form part of humankind's cultural heritage and therefore should be preserved (McDowell 1988).

d) Undiscovered or undeveloped values

Ecosystems are viewed as representing potential sources of medicine, food and building materials etc. As such they represent an important untapped resource which may be vital for the survival of humankind (Ehrenfeld 1976).

e) Environmental baseline and monitoring values

Natural ecosystems are of use in monitoring changes in the earth's physical environment (Schindler 1987). For example, lichens are sensitive indicators of air pollution, especially

dust and sulphur dioxide (Brandt 1972); phytoplankton are sensitive to water pollution (Schindler 1987).

f) Scientific research and teaching values

Many species have some special characteristic that makes them extremely valuable to scientists. For example, squids (Order Teuthoidea) and the sea hare (*Aplysia*) have nervous system properties that make them of immense value to neuroscientists (Barnes 1980). Natural ecosystems provide a wealth of knowledge for scientists, teachers and students alike.

g) Ecosystem stabilization values

These values are at the heart of the controversy that has arisen over the theory of natural ecosystem conservation. It has long been known that intensive monocultures have a higher risk of epidemic disease and vulnerability to pests and diseases than do natural systems (Ehrenfeld 1976). The reduction in genetic diversity results in closely related crop plants, which in turn facilitates the spread of both pests and disease organisms. It also eliminates plant species which shelter the natural enemies of specialized pests (Ehrenfeld 1976).

Humans can cause irreversible change in the natural order, resulting in the loss of an evolved gene pool or community, which in turn, may carry a hidden and inestimable risk of serious damage to humans and civilization.

The crux of the conservation debate is that extinct species and

communities cannot be recreated and their future benefit to humanity will have been destroyed with them.

1.2 WHY CONSERVE THE ROBERTSON KAROO?

Few species or communities in the Karoo have proven utilitarian importance for humanity. Reasons for their conservation are thus confined to their aesthetic, recreational, cultural, ethical and research values.

The Robertson Karoo is the southern most part of the Succulent Karoo Biome which contains a great richness of succulent plant species belonging mainly to the Mesembryanthemaceae and Crassulaceae (Rutherford & Westfall 1986). The species diversity is high for an arid region and there are a number of endemic (Werger 1978) as well as threatened (Hall *et al.* 1980) species. In the Robertson Karoo many plant communities which appear to be threatened by agricultural and urban expansion (Hilton-Taylor & Le Roux 1989).

The dominant vegetation of the Robertson Karoo, together with the Little Karoo, is classified as one of the three variations of Karroid Broken Veld (Acocks 1953). The natural vegetation of the Robertson Karoo differs from the that of the Little Karoo in the occurrence of minor plant species (B. Bayer pers. comm.), thus forming a unique assemblage of plant species.

Hilton-Taylor & Le Roux (1989) note the existence of numerous

studied or documented the threats faced by those ecosystems. An example of the latter approach is the work of McDowell (1988) in which he assesses agriculture as a threat to West Coast Renosterveld. McDowell (1988) concludes that an assessment of the threats faced by natural ecosystems is an important supplement in establishing a conservation strategy for these ecosystems. A pilot study and literature review indicated that the main threats in the Robertson Karoo appear to be agricultural and urban expansion (Hilton-Taylor & Le Roux 1989).

As well as a study of the threats it is also vital to identify areas within the study area which are of ecological significance. This information, together with the information on threatened areas, will allow a list of priority conservation areas to be formulated.

The objectives of this study are, accordingly:

- a) To discuss the historical development of the Robertson Karoo environment.
- b) To determine the present extent of the natural vegetation and its rate of decrease.
- c) To evaluate the factors, i.e. agricultural expansion and urbanization, which threaten the natural vegetation by:
 - i) assessing agricultural land use trends over the last 50 years.
 - ii) determining major agricultural activities of today.
 - iii) calculating the rate of urban expansion.

- d) To investigate other potential threats to the natural vegetation.
- e) To predict the changes that might occur in the future.
- f) To determine comparative agricultural potentials for the Robertson Karoo and to see how these potentials can predict future agricultural expansion.
- g) To map areas of conservation value.
- h) To identify priority conservation areas, by assessing the threats to areas of ecological interest and value.

1.4 THE STUDY AREA

The Robertson Karoo is situated midway down the valley of the Breede River (Fig. 1.1) in the winter rainfall region of South Africa.

1.4.1. Delimitation of the study area

The exact delimitation of the study area (Fig. 1.1) was based on Hilton-Taylor & Le Roux's (1989) biogeographic area, the Worcester-Robertson Karoo, and Joubert's (1968) map of the Robertson Karoo. Other sources, such as the Acocks' (1953) Veld Type map, were also consulted. The 600m contour line was chosen as the boundary of the study area in the north, west and south as it included the areas of the Worcester-Robertson Karoo mapped by Hilton-Taylor & Le Roux (1989) and Joubert's (1968) Robertson Karoo. In addition the 600m contour line corresponds approximately with the 600mm precipitation isohyet. This is significant since, in the South Western Cape, a mean annual precipitation of 600mm is the upper limit of karoo and

renosterveld vegetation. Areas with precipitation above this are predominantly covered by fynbos vegetation (Campbell 1985). The 20°15' longitude line was chosen as the eastern boundary, as it is just east of the boundaries of Hilton-Taylor & Le Roux's (1989) Worcester-Robertson Karoo and Joubert's (1968) Robertson Karoo. The study area, hereafter referred to as the Robertson Karoo, therefore covers an area of approximately 2332km² and includes the karroid plains, the transitional zones to Mesic Mountain Fynbos in the north, west and south and the transitional zone to Coastal Renosterveld in the east.

1.4.2 Climate

The climate is typically mediterranean, with the winter precipitation being low (125-350mmyr⁻¹, Fig. 4.4). Although the precipitation is low, the run-off from the mountains is plentiful as evidenced by the many streams, the Breede River and its major tributaries - the Riviersonderend and Hex rivers. Summers are hot, with a mean maximum temperature in January of 29.2°C. Winter nights are cold, (mean minimum for July = 7.1°C) with frost in low-lying areas (Anon. 1985a).

1.4.3. Geology

The Robertson Karoo lies in the Cape Fold belt (Du Toit 1954) and has a complex geology (Fig. 4.1). The most conspicuous geological structure is the Worcester fault, which stretches from Mossel Bay, in the east, to Piketberg, in the northwest (Greeff 1978).

In simple terms, the area consists of quartzite and sandstone of the Table Mountain Group in the mountains, and of siltstone and shale of the Bokkeveld and Witteberg Groups in the valleys (Le Roux 1983). In some places the Bokkeveld series are overlapped by the Dwyka formation of the Karoo system (Du Toit 1954). The quartzites and shales of the Witteberg series appear in the Roodeberg and run northwards beneath the Karoo systems of the Breede River valley as a result of intense down-faulting (Du Toit 1954).

1.4.4 Soils

The complex geology results in a wide variety of soils (Fig. 4.2). The Table Mountain sandstones of the Langeberg foothills form whitish or grey porous sandy soils. These soils are nutrient-poor owing to their high silica content and to a lack of feldspar, mica and clay (Du Toit 1954). The Bokkeveld shales in the valleys, on the other hand, form fertile clay-rich soils, and in the floodplains along the rivers there is fertile alluvial soil (Du Toit 1954). As a result, apart from those developed in the Langeberg foothills, the soils of the region have a fairly high nutrient content (Anon. 1985b). To the west the soil is mostly shallow and has a lime horizon in the undersoil (Joubert 1968, Anon. 1985a & b). The Breede River floodplain in the vicinity of Bonnievale consists of deep red apedal and textured soils, many of which have a high sodium content in the subsoil (Joubert & Stindt 1979). As a result of low rainfall and minimal plant growth, the soils are deficient

in organic material (Joubert 1968). A major problem is salinization which is common in arid and semi-arid regions where evaporation exceeds precipitation, leading to high concentrations of salts in run-off, groundwater and impoundments (Dr. Moolman pers. comm.).

1.4.5. The natural vegetation

The dominant vegetation of the Robertson Karoo, Karroid Broken Veld (Veld Type 26, Fig 1.2) is defined by Acocks (1953, p.86) as "karoo veld dotted with dwarf trees and shrubs, and including varying amounts of grass and succulents". The hills and mountains surrounding the area are covered by Veld Types 69 (Macchia) and 70 (False Macchia) in the north and south; and Veld Type 43 (Mountain Renosterveld) in the southwest. In the east of the study area Veld Type 46 (South Coast Renosterveld) occurs (Acocks 1953).

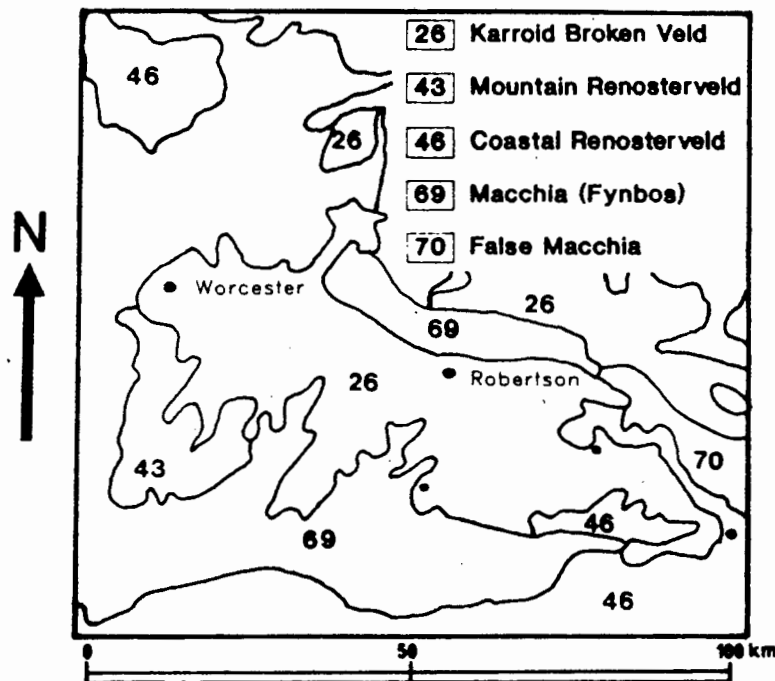


Fig. 1.2: Veld Types of the Robertson Karoo (after Acocks 1953)

In the 1960's and 1970's Joubert (Joubert 1968, 1970, Joubert & Stindt 1979) undertook a survey of the different vegetation communities in the Robertson Karoo (Fig. 1.3). Joubert's (1968) vegetation survey is the most comprehensive, although even this concentrates mainly on the dominants. He divided the Robertson Karoo into eight plant communities:

i) *Euphorbia mauritanica* and *Pteronia paniculata* communities.

These communities occur in patches on the low-lying plains at altitudes ranging from 180m above sea-level and on north-facing as well as south-facing slopes of less than 2%.

ii) *Pteronia incana* community. This community occurs on south-facing slopes and mountains exceeding a 20% gradient.

iii) *Salsola glabrescens* - *Acacia karroo* community (termed dry river community in Fig. 1.3). This community is limited to the smaller seasonal streams which feed the Breede River. A large amount of alien vegetation (e.g. *Sesbania punicea*; personal observations) occurs along the larger rivers.

iv) *Elytropappus rhinocerotis* community. This community is found on south-facing slopes at altitudes above 250m. Above 500m it may be found on slopes of all aspects.

v) *Euclea undulata* community. This dwarf tree or tall shrub community occurs between 180-220m in the valleys.

vi) *Crassula rupestris* community. This community is limited to altitudes between 200-500m above sea-level on north-facing, mountain slopes with a gradient ranging from 20% to 50%.

vii) *Elytropappus* - *Willdenowia* community. This community is found on low-lying flats between 200-320m with slopes less than 20%

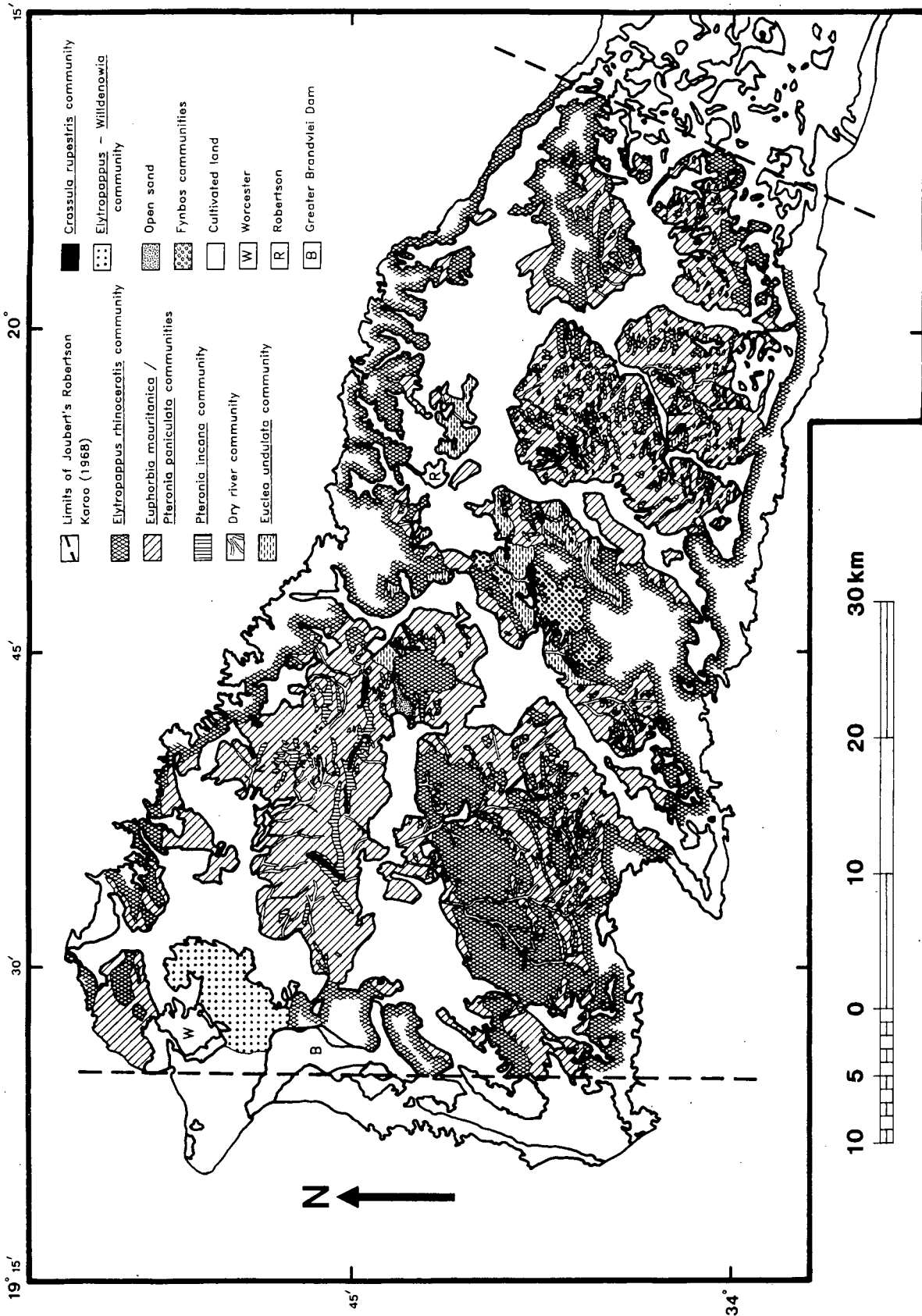


Fig. 1.3: Vegetation communities of the Robertson Karoo (after Joubert 1968)

Of the nine dominant species from the seven communities, only three species are considered by Joubert (1968) to be "palatable" (where palatability can be defined as plant characteristics or plant conditions that stimulate the animal to graze the plant; Heady 1964), viz: *Salsola glabrescens*, *Acacia karroo* and *Euclea undulata*. (*Pteronia paniculata* and *Euphorbia mauritanica* are only grazed to a limited extent.) The average percentage crown cover of "palatable" species in all the communities was found to be 19.5% as opposed to 59.4% for "unpalatable" species. Joubert (1968, 1970), Joubert & Stindt (1979) concluded that the Robertson Karoo was dominated by "unpalatable" shrubs, assumed to be a consequence of overgrazing. The current grazing capacity of the area is low, with the recommended grazing capacity valued at 1 small stock unit per 8ha (B. Bayer pers. comm.). Own observations from aerial photographs and field experience show the karroid vegetation to be extensively eroded and much of the topsoil appears to be lost.

The total area covered by the natural vegetation in the Robertson Karoo appears to have been drastically reduced due to the encroachment of agricultural lands and urbanization (Hilton-Taylor & Le Roux 1989).

1.5. STRUCTURE OF THIS THESIS

Chapter 2 describing the historical changes in the Robertson Karoo environment follows. An assessment of the threats to the

natural vegetation is then dealt with in Chapters 3 and 4. In Chapter 5 areas of high conservation priority are identified and the implications for a conservation strategy in the area are discussed. Finally, in Chapter 6, the general conclusions of this thesis are given.

**CHAPTER 2: AN HISTORICAL PERSPECTIVE OF
THE ROBERTSON KAROO ENVIRONMENT**

2.1 INTRODUCTION

The aim of this chapter is to provide an historical perspective of the Robertson Karoo environment. The Robertson Karoo today (see Chapter 1) consists of karroid plains dominated by Karroid Broken Veld (Veld Type 26, Acocks 1953) and is surrounded by transitional zones to Mesic Mountain Fynbos in the north, west and south, and to Coastal Renosterveld in the east. The area is transversed by the Breede River. Each of the above communities has reacted differently to the changing environment and land use patterns.

Although the history of the Robertson Karoo environment has not been documented to any great extent, various authors, notably Acocks (1964, 1979), have commented on its past vegetation and how it had changed. Joubert (1968, 1970), in addition, commented on the contemporary vegetation and the past causes of change. Both Acocks (1953, 1964, 1979) and Joubert (1968, 1970) ascribed to the Clements (1916) successional theory, thus they assumed that the Robertson Karoo was at some point in the past a "steady state" or "climax" community in equilibrium with the environment. This "climax" community, which was supposedly dominated by palatable perennial shrubs and grasses, was interpreted as having been degraded by some factor resulting in the communities seen today ("disclimax" communities). There are various problems with the concept of "climax" communities. These states, especially in arid and semi-arid regions which are characterized by relatively unpredictable climatic and disturbance regimes, may be the exception rather than the rule

(Hoffman 1988). Hoffman (1988) concludes that it was unlikely that steady states ever occurred in historical times. Thus sequential and deterministic replacement sequences are unlikely. A particular climatic sequence may favour one species over another and this effect may last for decades, giving an apparent "steady state" condition (Noy-Meir 1973). As an example of this, grass domination is a well known response to influence of high summer rainfall (Roux & Vorster 1983, Hoffman 1988).

2.1.1 Conventional ideas on the past Robertson Karoo environment

In his 1964 and 1979 works, Acocks commented on past vegetation patterns (the "climax" communities) of the Robertson Karoo. He suggested that prior to European colonization there was probably a mixture of karoo bush, large and small succulents, grass, shrubs and trees, with thickets of *Euclea undulata*, *Carissa haematocarpa*, *Zygophyllum foetidum*, *Putterlickia pyracantha*, *Euphorbia mauritanica* and *Cotyledon paniculata sensu lato*. He suggested that these thickets probably thinned out along the less arid footslopes of the mountains into grassy veld, which is now Renosterveld (Acocks 1979). The non-succulent, semi-arid karoo bushes which were apparently once plentiful have today been replaced by weedy Mesembryanthemaceae species (Acocks 1964).

Acocks (1979) further suggested that the gallery forests (forests alongside the rivers) were more extensive than that of today, and probably included such species as : *Podocarpus*

elongatus, *Rapanea melanophloeos*, *Brabeium stellatifolium*,
Acacia karroo, *Kiggelaria africana*, *Brachylaena neriifolia*,
Freylinia lanceolata, *Rhus angustifolia*, *Melianthus major*, *Ilex*
mitis, *Lachnostylis hirta*, *Psoralea aphylla*, *Salix capensis* and
Myrica serrata.

Acocks (1979, p.685) suggested of the the Breede River that:
"the river itself and its major tributaries, the Riversonderend
and Hex rivers, are permanent and would have been deep and slow
running, much impeded by *Prionium*, *Typha* and *Phragmites*".

P.A.B. van Breda (pers. comm.) mentioned the presence of natural
forests in the area, of which a few examples are left in the
kloofs. It appears that the low rainfall of the area would have
been insufficient to support an extensive forest (Acocks 1979).
So-called "relics" of forest in kloofs are similar to the
gallery forests with some additions: e.g. *Metrosideros*
angustifolia, *Cunonia capensis*, *Rhus lancea*, *Buddleia*
salicifolia, *Acacia karroo*, *Rhus pyroides* and *Maytenus cymosus*
(Acocks 1964).

Acocks based his pre-colonial plant species list on the
rationale of "relic" plant species. He suggested that the
occurrence of a "relic" species in a community today, indicates
that this species was once a dominant component of the
undisturbed community. There are many problems with this logic,
not the least of which concerns the definition of a "relic"
plant species and the assumption that it was once more

widespread.

2.1.2 Conventional wisdom regarding the contemporary Robertson Karoo environment

Studies (Joubert 1968, 1970, Joubert & Stindt 1979) conducted in the Robertson Karoo concluded that the vegetation is now dominated by "unpalatable" shrubs (see Chapter 1, section 1.4.4). They also noted the soil to be eroded. Although it is unclear as to the extent of the erosion, personal observations from aerial photographs and field experience indeed do show the soil to be extensively eroded and much of the topsoil appears to have been lost. Joubert (1968, 1970, Joubert & Stindt 1979) attributed the above to overgrazing, especially as a result of the European settlers over the last 100 years.

2.1.3 Ideas of vegetation change and the possible causes

The causes of the assumed changes were almost entirely ascribed to man (Acocks 1953, Roux & Vorster 1983, Vorster 1983). Acocks (1953) in particular attributed the vegetation changes to be a result of the differences in the grazing regimes of the pre- and post- colonial animals.

The popular view holds that, prior to the introduction of domestic stock in colonial times (i.e. around 300 years ago), karoo plant populations were at, or near, a "stable equilibrium" with the environment (Acocks 1953, 1955, 1964, Roux & Theron 1987). This "stable equilibrium" or "climax state" is considered

to have been in so-called equilibrium with environmental conditions, which included a large population of many species of migratory wild animals, both grazers and browsers. At these times, the vegetation would not have been grazed continuously, although grazing could have been periodically heavy with virtually all the species being utilized by the herbivores (a form of non-selective grazing). Such a grazing regime would alternate between periods of heavy grazing/defoliation with variable rest periods (Acocks 1966)). The replacement of dominant wild animals by cattle and sheep, which are highly selective feeders, then resulted in imbalances e.g. the ratio of domestic grazers to browsers is believed to be higher than that which existed for indigenous grazers and browsers (Downing 1978). Researchers regard this as the main reason for the increase of woody species with the accompanied decrease in herbs (Acocks 1955, Downing 1978, Roux & Theron 1987). In addition the domestic animals of the Europeans grazed continuously. The above resulted in a continuous selective grazing regime. A continuous grazing regime allows at least some animals to be kept in the pastures throughout the period when the vegetation is grazable (Booyesen 1967). This continuous selective grazing favours "unpalatable" species and woody shrubs (Acocks 1955).

There are certain problems with the above ideas of pre- and post-colonial vegetation and its change. The first, involving the concept of "equilibrium" or "climax states", has already been mentioned (see section 2.1). A second problem involves the effects of different grazing regimes. There is no conclusive

evidence of the precise effects of different grazing regimes or whether they radically alter species composition in the Karoo (Hoffman 1988). Thirdly, there is some doubt concerning the contention that the indigenous herbivores did in fact graze non-selectively (Hoffman 1988). Finally, the researchers (Acocks 1953, Downing 1978) make no mention of the large herds of domestic Khoi livestock which occupied large areas of South Africa, particularly the South Western Cape, before the European settlement of the 18th century. Other researchers (Deacon 1983) make the point that the Khoi were also practising a form of non-selective grazing, as they were reported by the early travellers' to graze an area "bare" before they moved on (Thom 1958).

2.1.4 The need for reassessment

The ideas of Acocks' (1953, 1955, 1964, 1966, 1979), Joubert's (1968, 1970) and Joubert & Stindt (1979) appear to be based on erroneous assumptions and therefore need to be re-evaluated. To do this, it is necessary to gather additional information on the past Robertson Karoo environment and how it has changed. This can be achieved by reviewing history of the past inhabitants and discussing the possible impacts they had on the Robertson Karoo environment, especially their effects on the vegetation and soil cover. In addition, the more notable documented descriptions of past vegetation are studied. As well as anthropogenic effects, other possible determinants of vegetation change are reviewed. Finally, in the light of these, a reassessment is made on the

ideas (Acocks 1953, 1955, 1964, 1966, 1979; Joubert 1968, 1970) presented above.

2.2 RESULTS AND DISCUSSION

2.2.1 Anthropogenic activities

The Robertson Karoo has had a long history of human influence. Table 2.1 documents the history of human settlement in the Robertson Karoo and its major impacts on the vegetation.

2.2.1.1 Pre-colonial events (before 1652 AD)

The impacts of the San people (hunter-gatherers) on the vegetation are unknown. One possible impact they might have had on the vegetation involved their use of fire. The San and later the Khoi, used fire to destroy old grass and attract wild animals with the new growth (Burchell 1822), thus changing existing natural regimes. Khoi also burnt old pasture on which cattle could no longer graze (Kolbe 1727 cited by Botha 1962). It is impossible to tell if the San and Khoi burnt the karroid plains, although karroid vegetation does not burn easily (Booyesen & Tainton 1984). Hence, it is probable that they concentrated on the more grassy surrounding renosterveld.

Due to their pastoral activities, the arrival of the Khoi may have caused a further change in the vegetation. Although it has been suggested that both the indigenous herbivores (Acocks 1955, Downing 1978) and the Khoi livestock grazed non-selectively (Deacon 1983), Hoffman (1988) strongly opposes this

Table 2.1: The history of settlement in the Robertson Karoo and possible impacts on the vegetation.

DATE	EVENT	IMPACT
	No prehistoric history of fire	
Prior to 21000-2000 BP	San (hunter-gatherers) and a large variety of herbivores inhabited the Robertson Karoo ^{1,2}	Little long-term effect Wild herbivores - NSG?
1600-2000 BP	Nomadic pastoralists (Khoi) arrived ³⁻⁹ . They kept fat-tailed sheep which appeared to arrive before their horned cattle ^{6,9,10} . Historical records 15th century onwards record large herds of livestock in the southern and western Cape ¹¹ . Populations estimates for the SW Cape ranged from 45000-100000 ⁵ . The Breede R. valley was part of the lands of the Chainouqua tribe who also pastured in the Salt and Riversonderend river valleys. Population estimates = 16000-18000 ⁵ .	First impact of domestic stock on vegetation. NSG? Historical accounts record large herds of Khoi livestock grazing the vegetation bare before they moved on ¹² . The Khoi introduced large herds of selective grazers compared to the indigenous grazers and browsers (Table 2.2). Impact on the immediate surroundings of a kraal? Ethnological evidence from Namaqualand suggests kraals caused minimal impact ¹¹ . Robertson karoo - arid at this time?, if so Khoi would have kept to better watered areas.
	Both the San & Khoi used fire to attract wild animals ¹³ . Khoi also used fire to enhance the grazing of the natural vegetation.	Unknown if the inhabitants burnt the Robertson Karoo.
1652 AD	Dutch India East Company formed refreshment Station at Cape Town ¹⁴ . Farmers migrated away from the Cape in search of grazing for their livestock (mutton sheep and Afrikaner cattle) ¹⁴ .	
1713	Smallpox epidemic drastically reduced Khoi population numbers ¹⁴ .	
1714-1726	Robertson Karoo settled by European farmers ¹⁴ , especially along the banks of the rivers. Farmers obtained grazing rights or loan farms ¹⁵ . Theoretical minimum size = 3000morgen (2570ha)	
1746	Town of Swellendam established	
1819	Worcester founded	
1853	Robertson established	
	Population densities remained low. Herds of indigenous herbivores and Khoi livestock would have disappeared. Replaced by mutton sheep and Afrikaner cattle.	Little effect on the veld as a result of low population densities?

Fire does not play a role in rangeland utilization?

Early 1800's	Until this period agricultural development was slow, due to low and irregular rainfall and the distance from markets ¹⁶ .	
1853	Bainskloof pass was built, establishing a viable route between Worcester and Cape Town. By this time vineyards at Worcester were well established ¹⁷ . There were only a limited number of vineyards at Robertson.	Reduction in area of natural veld.
1857-1860	First lucerne planted on farm near Worcester ¹⁸	
	During this time lands were not fenced, livestock would have been herded. Sheep and goats were the most common livestock due to arid conditions.	Livestock CG?
After 1897	Fencing of domestic animals was introduced ¹⁹ . Farms became smaller, divided into inherited units.	Increased grazing pressure. Overstocking during good years - disastrous effects during subsequent dry years ²⁰ .
1909	Continued overproduction of wine, led to a collapse in the industry. Fortunately the ostrich market was flourishing. All existing vineyards were ploughed up to plant lucerne to feed ostriches. These animals also grazed on the natural veld ¹⁶ .	Ostriches can cause considerable damage to veld ²¹ . However, they feed mainly on lucerne thus effects on the veld were probably confined to trampling.
1913	Ostrich market collapsed and farmers returned to wine farming. Livestock are still an important farming activity.	Increased grazing pressures degraded veld
1923	Building of Brandvlei Dam ²² .	The area under cultivation increased. Livestock farming became less important. The extent of the Breede R. floodplain was reduced.

References:

- | | |
|-----------------------------------|-----------------------------------|
| 1 = Hall 1978 | 12 = Thom 1958 |
| 2 = Theal 1888 | 13 = Burchell 1822 |
| 3 = Cooke 1965 | 14 = Elphick & Giliomee 1989 |
| 4 = Deacon 1983 | 15 = Guelke 1984 |
| 5 = Elphick 1985 | 16 = Luckhoff 1946 |
| 6 = Klein 1986 | 17 = Kench <i>et al.</i> 1983 |
| 7 = Robertshaw 1978 | 18 = Heatlie 1981 |
| 8 = Stow 1905 | 19 = Grigg 1974 |
| 9 = Von der Driesch & Deacon 1985 | 20 = Hilton-Taylor & Moll 1986 |
| 10 = Scheitzer 1974 | 21 = Nel pers. comm. |
| 11 = Deacon <i>et al.</i> 1978 | 22 = Schreüder <i>et al.</i> 1988 |

KEY: NSG = Non selective grazing; CG = Continuous grazing (see Hoffman 1988).

Table 2.2: Historic herbivores of the Robertson Karoo

Bulk Grazers	Concentrated Grazers	Browsers
Cape Buffalo	Wildebeest	Eland
Quaggas	Bontebok	Blue Duiker
Zebra	Grey Rhebok	Grey Duiker
	Red Hartebeest	Steenbok
	Hippopotamus	
	Warthogs	Klipspringers
		Ostriches
Baboons	Baboons	Baboons

Ratio of indigenous grazers to browsers = 10:7

Khoi introduced herds of selective grazers:

Domestic Cattle Domestic Sheep

*Elephants were excluded as it is uncertain if these animals were present in the Robertson Karoo.

**The domestic goat is also excluded as goats were unknown or rare in the South western Cape.

References: Skead 1986
 Smithers 1983

idea, stating that it is based on circumstantial evidence and is essentially untestable. The large herds of selective grazers introduced by the Khoi may indeed have had an effect as their grazing diets would perhaps have been different from the indigenous herbivores (Table 2.2). This suggestion is supported by evidence from other karroid areas, e.g. the Nuweveldberg (Meadows & Sugden 1988) where there is strong evidence that the Khoi herders affected vegetation composition.

The Khoi, especially if they occupied a kraal for an entire year, may have had a marked impact on the immediate surroundings. Such a contention is supported by Sampson (1984) working in the Eastern Cape. Ethnological evidence from Namaqualand, on the other hand, suggests that the Khoi kraals had a minimal effect on the vegetation (Table 2.1, Deacon *et al.* 1978).

It seems probable that the Khoi would have settled in the better watered and grassy areas such as the Breede River floodplain and eastwards towards Swellendam (see section 2.2.1). Hence, the karroid vegetation itself may have been grazed only to a limited extent, more especially by the indigenous browsers which were present. In fact there is a possibility that the Khoi livestock were never present in large numbers in the Robertson Karoo at all. Supporting this is the evidence from travellers' records which note that the Khoi were more abundant along the coastal plains (Deacon *et al.* 1978).

2.2.1.2 Post-colonial events (after 1652 AD)

The arrival of the European settlers was an important event which changed the course of South African history dramatically. Their arrival was also important as for the first time the appearance of the vegetation was documented.

a) Travellers' records

The early European travellers' records is a major source of past vegetation descriptions. However, these descriptions were mostly confined to well travelled routes. In addition they are were also often vague or exaggerated, probably because the travellers were foreign (mainly from Britain and the Netherlands) and the vegetation of South Africa was vastly different to any they had previously encountered.

Unfortunately only a relatively small number of travellers' records can be found for the Breede River valley and it appears that the valley was not a well travelled route. The more notable observations are recorded in Table 2.2. Backhouse (1844) referred to the valleys as extensive and grassy, which contradicts all the previous records, e.g. Thunberg (1793/95) and Sparrman (1786) who observed the plains (map location A & B, Fig 2.1) to be "carro". It seems unlikely that the vegetation of the karroid plains between 1772 and 1840 suddenly changed from "carro" to grassy plains well supplied with water. I conclude that Backhouse (1844) was referring specifically to the Breede River floodplain itself.

Table 2.3: Certain more notable traveller's observations.

1) Karroid plains

Date	Traveller	Map Location	Observation
1772 Oct	Thunberg	A	"the carro" plains which are very dry, sterile and bare of grass; being covered with a great number of succulent plants" ¹ Notes following plant species (new species name, if applicable appears in brackets): <i>Mesembryanthemum edule</i> (<i>Carpobrotus edulis</i>), <i>Arduina bispinosa</i> (<i>Carissa bispinosa</i>), <i>Mimosa nilotica</i> (<i>Acacia karroo</i>), <i>Viscum capense</i> , <i>Rhus</i> ² .
1773 Oct	Thunberg	A	"The field was of the karroid kind, and the sheep were said to feed on these succulent plants, the mesembryanthemums" ³
1776	Sparrman	A	"This tract of country was partly of the carrow kind" ⁴

2) Plains to the east (Swellendam district) and mountain foothills surrounding the area

Date	Traveller	Map Location	Observation
1773 Nov	Thunberg	B	"The country here began to be very hilly, and abound with grass, and at the same time had a sufficient number of rivulets, and wood in the clefts of mountains" ⁵

3) Breede River

Date	Traveller	Map Location	Observation
1830	Anon.	C	The Breede River during the rainy season often overflowed its banks to "a great distance" ⁶
1840	Backhouse	D	"by the side of the Breede a pink heath was in blossom among the rushy herbage" ⁷
		E*	"the valleys in this part of the country are extensive, grassy, well supplied with water" ⁷

¹ see Fig. 2.1

² Karoo - carro or carrow is derived from the Hottentot word meaning dry, hard or difficult (Nienaber & Raper 1977).

* It is assumed that Backhouse is referring to the Breede River floodplain.

References:

- | | |
|-----------------------------|-----------------------------|
| 1 = Thunberg 1793/95, p.70 | 5 = Thunberg 1793/95, p.208 |
| 2 = Thunberg 1793/95 | 6 = Steedman 1835, p.62 |
| 3 = Thunberg 1793/95, p.205 | 7 = Backhouse 1844, p.612 |
| 4 = Sparrman 1786, p.247 | |

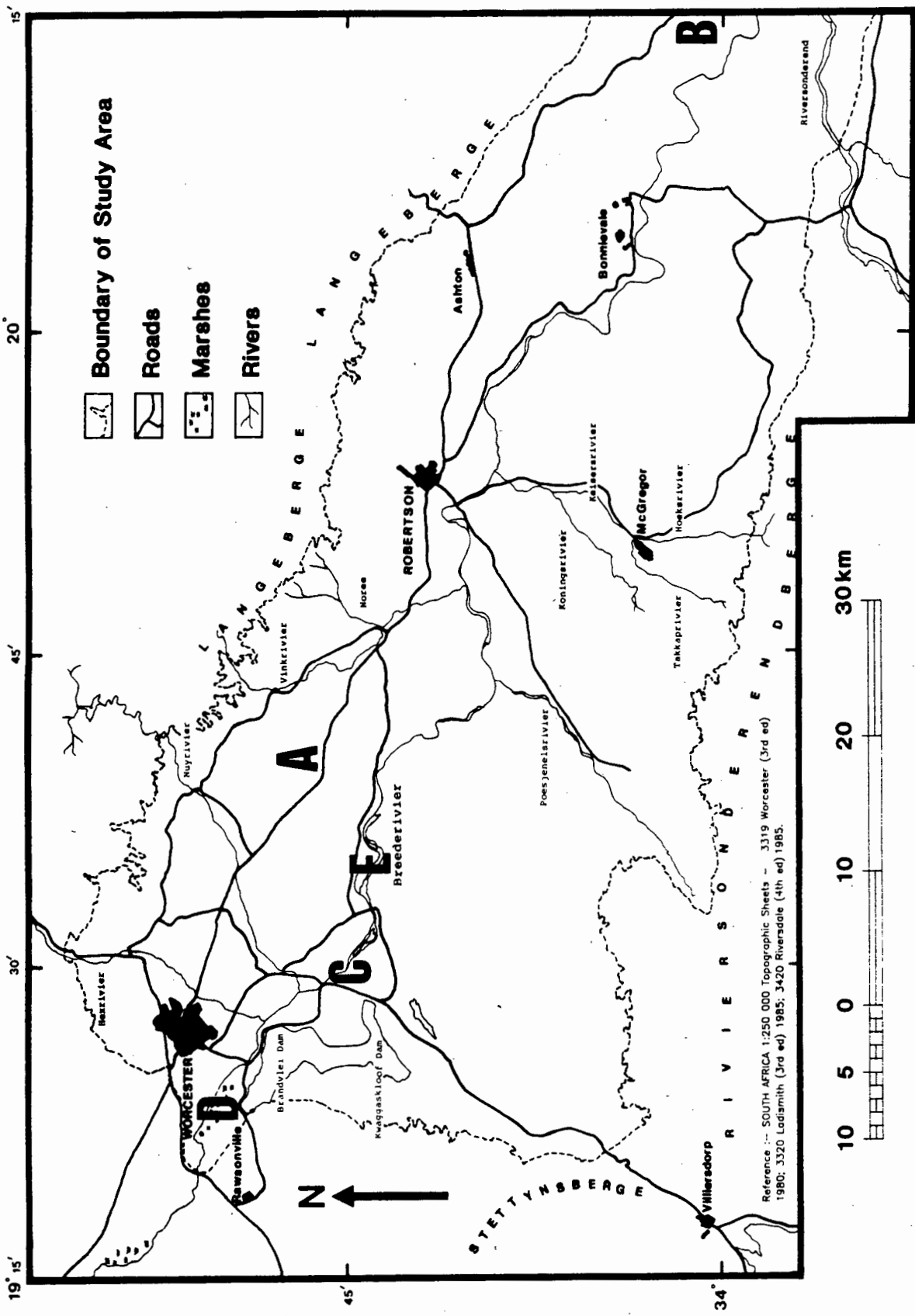


Fig. 2.1: Regions described in travellers' records (see Table 2.3)

It is unclear whether the plants collected by Thunberg (1793/95) in 1772 were dominant species, or were merely species of interest to him. *Acacia karroo*, a "palatable" species, is the only species which Thunberg mentioned that is still dominant today, albeit in localized areas along rivers. He states that *Acacia karroo* "supplies plenty of wood" indicating perhaps that this species grew in greater abundance in historical times. He does not mention the dominant "unpalatable" species present today, e.g. *Euphorbia mauritanica*; but Thunberg (1793/95) does mention certain "palatable" species, e.g. *Zygophyllum morgsana*. It cannot be assumed, however, that the past vegetation was dominated by a higher percentage of "palatables" species than today.

The evidence available from travellers' records does give credence to a number of Acocks (1964, 1979) suggestions (see section 2.1.1). It does appear that the Breede River was deep, slow running and much impeded by rushes and sedges. The slopes of mountains surrounding the area were grassy and the forests in the kloofs were perhaps more extensive than that of today. Whether the non-succulent, semi-arid karoo bushes were once plentiful or whether the gallery forests were more extensive than today as suggested by Acocks (1955, 1964, 1979), remains obscure as there is a dearth of literature on this subject.

To conclude, the available information suggests that, at the time of the early European settlers, the karroid plains of the Robertson Karoo consisted of an arid vegetation type which was

dominated by shrubs with a low grass component, but it is not clear whether the species composition within the vegetation has changed since the early European settlement. The natural vegetation of the Swellendam district (east of the karroid plains) and surrounding mountain foothills, today Renosterveld, appears to have had a higher grass component than that of today. It would seem that the Breede River formed a wide flood plain which was covered by grass species.

b) Historical events and their impacts (after 1652 AD)

Before the 19th century the population densities of the area were low, probably resulting in minimal impact on the environment. However later the increasing European population could have affected the environment as a result of grazing, agricultural expansion, urbanization and fire regime alteration.

i) Grazing: Later settlement expansion during the 19th and 20th centuries would have changed the existing grazing regimes (see section 2.1.3). Hoffman (1988) points out, however, that there is no conclusive evidence as to the precise effects of these different grazing regimes and whether they radically alter species composition in the Karoo. If the Khoi domestic livestock did not graze on the Robertson Karoo vegetation (see section 2.2.1.1), the possible differences between the diets of the European settlers' livestock and those of the indigenous herbivores may have had an impact on the vegetation.

The increasing populations both of people and livestock would have caused increasing pressures on the land and a greater likelihood of an impact. However, although today the karroid plains of the Robertson Karoo appear to be eroded (personal observation) and are dominated by unpalatable species, there is no evidence as to the exact nature of vegetation change. In contrast, the surrounding Renosterveld, apparently grassveld at the time of the arrival of the European settlers (see section 2.2.1.2), does appear to have been changed with the grazing practices of the Europeans being one of the possible causes (Cowling *et al* 1986).

ii) Agricultural Expansion and Urbanization: Agricultural and urban expansion has transformed a large proportion of the natural vegetation of the Robertson Karoo to cultivated land and urban areas. Irrigation became an important factor. As early as the 18th century the farmers flood-irrigated their fields using the natural flow of the river (Shreüder *et al.* 1988). During the 19th century a series of irrigation channels were constructed to provide water to the expanding agricultural fields (Shreüder *et al.* 1988). These, together with the construction of Brandvlei Dam in 1923, controlled the flood waters of the Breede River. This was one of the main causes for the reduction in the extent of the Breede River floodplain.

iii) Fire: Shortly after the European settlement began, the Government prohibited veld burning and passed laws against its practice (Botha 1962). It appears that veld burning was never a

standard practice in the arid Robertson Karoo and thus has not had a major impact on the environment. Nevertheless, veld burning did become an established practice chiefly in the grassy eastern areas and the mountains of the Karoo (Brown 1875, 1877, Anon. 1961). In the surrounding Renosterveld it seems likely that, in combination with other factors, a fixed fire cycle contributed to its change. Cowling *et al.* (1986) attributed the change from grassland to vegetation dominated by renosterbos to a fixed burning cycle and continuous grazing. He noted that the practice of immediate post-fire grazing was particularly harmful to the grass sward (Cowling *et al.* 1986, Hall 1934).

2.2.2 Alternative factors promoting vegetation change

A major determinant of vegetation and its change is climate. However the information that would be necessary to assess the effects of climatic change in this area is both fragmentary and unreliable (Tyson 1986) and thus not suitable for such an appraisal. It should be noted here that other authors, notably Acocks (1953, 1955, 1966), did not even take into account possible climatic changes. This is a serious gap in the understanding of vegetation change in the Robertson Karoo which needs to be filled.

Climate, through precipitation, has an important influence on the dominant growth form of a vegetation. Hemicryptophyte growth is favoured by high summer rainfall, while chamaephytes tend to be dominant under winter rainfall conditions with low

rainfall in the four hottest months (Rutherford & Westfall 1986). In the past, as long as the Robertson Karoo experienced a winter rainfall regime with low rainfall in the summer months, it would probably never have had a high grass component and would have been dominated by chamaephytes. In the areas to the east of the Robertson Karoo, the rainfall is higher with a percentage falling in summer, suggesting that hemicryptophyte growth could have been more dominant (Rutherford & Westfall 1986).

2.3 CONCLUSIONS

There are no records of the vegetation before the 18th century and thus it is impossible to draw any conclusions as to what the vegetation was like.

Evidence indicates that in the early colonial times (18th century) the vegetation of the Middle Breede River Valley was dominated (as it is today) by karroid chamaephytes with a low percentage grass cover. It is not clear whether the vegetation had a higher percentage cover of "palatable" species than it does today (as postulated by Acocks 1953, Joubert 1968) and thus it is unknown if the species composition of the vegetation has changed to a great extent. However the Robertson Karoo appears to have been eroded and much of the topsoil has been lost. The Breede River was flanked by a wide grassy floodplain, which has been greatly reduced today. In addition much of the indigenous vegetation of the river banks have been replaced by alien infestations, e.g. *Sesbania*. In the kloofs, there could have

been a more extensive forest than there is today, although there is no historical evidence of extensive forests in this area. The area was surrounded by less arid grassy veld on the foothills of the surrounding mountains and in the plains east of the area, which today are dominated by unpalatable renosterbos (*Elytropappus rhinocerotis*).

The Robertson Karoo has had a history of human impact of at least 20 000 years. It is difficult, however, to conclude how the activities of the various inhabitants affected the vegetation of the karroid plains. Two possible scenarios exist: Firstly the soil erosion seen today together with other undetermined changes could have been caused by the combined effects of the Khoi pastoralists and later the European farmers. Secondly, if the Khoi had never settled in the Robertson Karoo, the possible changes could have been caused by the European farmers alone. The importance of natural factors such as climatic changes remains obscure.

The documented change in the vegetation of the Swellendam district and mountain foothills from grassveld of the early European settlement to the contemporary vegetation dominated by renosterbos appears to be a result of the change in a fixed burning cycle in combination with heavy grazing, especially post-burning grazing.

The reduction in the extent of the Breede River floodplain is

primarily due to floodwater control, especially the construction of Brandvlei Dam.

From the information gathered in this chapter, Acocks' (1953, 1955, 1966) and Joubert's (1968, 1970, Joubert & Stindt 1979) ideas describing the Robertson Karoo as a "climax" community and subsequently a "disclimax" community appear to be unfounded. However, their idea that the Europeans had an impact on the vegetation, especially in the Swellendam area, is correct. However, they may well have exaggerated the magnitude of impact of the European settlers and did not discuss the possibility of the Khoi and San people causing an impact on the vegetation, or of climatic change.

The most significant effect of the European settlers, was the reduction in the extent of the natural vegetation. This is the result of agricultural expansion of cultivated fields and to a lesser extent urbanization. These activities, which currently represent a major threat to the continued existence of the natural vegetation of the Robertson Karoo, are discussed in detail in the following chapters.

**CHAPTER 3: THREATS TO THE SURVIVAL OF
THE ROBERTSON KAROO AS A NATURAL AREA**

3.1 INTRODUCTION

This chapter investigates the threats to the continued existence of the natural vegetation in the Robertson Karoo. As discussed in the section 1.3, a knowledge of the threats to the natural vegetation of the Robertson Karoo is vital for predicting the future and for planning for the long-term survival of the vegetation. Further, Chapter 2 identified agricultural, and to a lesser extent urban, expansion to be the major threats. Agricultural expansion is indeed the largest threat, as 90% of the Robertson Karoo is privately owned farmland (B. Bayer pers. comm.). (Note: The Robertson Karoo is often referred to by Agricultural and Water Affairs officers as the Middle Breede River Valley).

Thus the objectives of this chapter are:

- a) To determine the present extent of the natural vegetation and its rate of decrease.
- b) To evaluate the factors, i.e. Agricultural and urban expansion, which threaten the natural vegetation by:
 - i) assessing agricultural land use trends over the last 50 years
 - ii) determining major agricultural activities of today
 - iii) determining the rate of urban expansion.
- c) To investigate other potential threats to the natural vegetation.
- d) To predict the changes that might occur in the future.

3.2 MATERIALS AND METHODS

3.2.1 Present extent of the natural vegetation and its rate of decrease

The following 1:50 000 topographic maps covering the whole study area were obtained from the Department of Surveys and Mapping, Cape Town:

- (i) Worcester 3319CB - 1st ed (1954); 3rd ed (1974)
- (ii) Villiersdorp 3319CD - 1st ed (1962); 2nd ed (1981)
- (iii) Nuy 3319DA - 1st ed (1959); 2nd ed (1977)
- (iv) Langevlei 3319DC - 1st ed (1961); 2nd ed (1974)
- (v) Koo 3319DB - 1st ed (1970)
- (vi) Robertson 3319DD - 1st ed (1961); 2nd ed (1974)
- (vii) Stormsvlei 3420AA - 1st ed (1962); 2nd ed (1982)
- (viii) Riversonderend 3419BB - 1st ed (1962); 2nd ed (1982)

The extent of the remaining natural vegetation was mapped for each topographic sheet and the area in km² was calculated using a Summagraphics ID Digitiser with AO table linked to a Tektronix 4051 graphic computer.

These data were compared to the work of Jeffery & Brown (1987) who mapped the remaining natural vegetation from Worcester to Bonnievale in 1987. The figures for the natural vegetation from Bonnievale to the eastern boundary of the study area were obtained from the work of S. Brown (1988a).

Values for the extent of natural vegetation in each area were obtained for the years: 1963, 1974 and 1987. If there was not a map edition available for the earlier years in a particular

area, linear regression between the available values provided the approximate figures. The extent of the natural vegetation was expressed as a percentage of the whole area.

A map of the extent of the remaining vegetation in the study area in 1987 was drawn from the maps produced by Jeffery and S. Brown (Jeffery & Brown 1987, S. Brown 1988a).

3.2.2 Agricultural and urban expansion

The population growth figures for the rural areas and urban areas of the Worcester, Robertson and Swellendam were calculated from census statistics (Central Statistics Services 1976a).

3.2.2.1 Agricultural land use trends since 1942

Seven areas (Fig. 3.1) were chosen as "case studies" to analyse the trends in land use. These areas, which covered 7% of the study area, were subjectively chosen in a pilot study to represent the spectrum of variation in farms and farming practices in the Robertson Karoo. Table 3.1 summarizes the characteristics of each chosen area, their boundaries corresponding to those of the original farms first settled in the 1700's.

For each area, land use patterns were mapped from aerial photographs onto 1:10 000 maps for the years 1942, 1966/67 and 1987. This was done using a Bausch & Lomb Stereo Zoom Transfer Scope in an attempt to eliminate distortions inherent in the

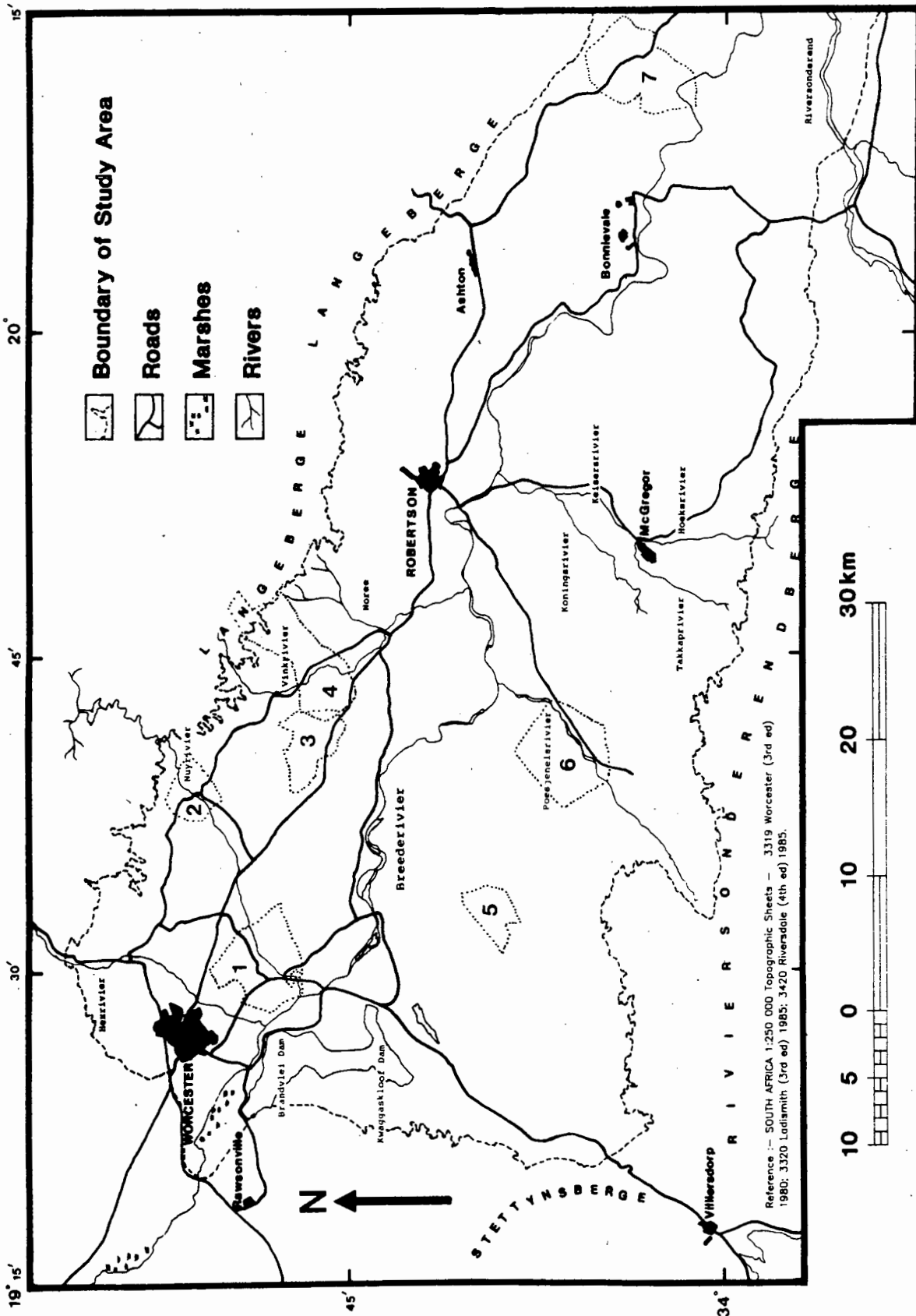


Fig. 3.1: The map locations of the seven representative areas: 1 = Aan de Doorns, 2 = Kloppersbosch, 3 = Koelefontein, 4 = Middelburg, 5 = Haumanskloof, 6 = Wandsbeck, 7 = Jan Harmens Gat

Table 3.1: Characteristics of the chosen areas

FARM	GRID REFERENCE	SIZE (km ²)	1st SETTLED	VELD TYPE	AGRICULTURAL ACTIVITY PRINCIPAL	LOCATION
1) Aan de Doorns	33°42'/S 19°30'/E	34	1731*	Karoo transitional to Renosterveld	Wine grapes	Breede River S of Worcester
2) Kloppersbosch	33°38'/S 19°38'/E	13	1731*	Karoo transitional to Renosterveld	Wine grapes	Nuy River E of Worcester
3) Haumanskloof	33°52'/S 19°33'/E	13	#	Karoo	Cattle	Sanberg hills S of Worcester
4) Wandsbeck	33°53'/S 19°40'/E	34	#	Karoo	Wine grapes	Poesjenelsrivier SSW of Robertson
5) Koelefontein	33°43'/S 19°40'/E	17	#	Karoo	Sheep, ostriches, goats	Mowers
6) Middelburg	33°43'/S 19°46'/E	24	#	Karoo transitional to Renosterveld	Cereals, Cattle	NW of Robertson
7) Jan Harmens Gat	33°58'/S 20°13'/E	37	1735+	Renosterveld	Cereals	SE of Ashton

* Aan de Doorns - Original grazing rights were granted on 22th March to P. Rossouw

Kloppersbosch - Original grazing rights were granted on 9th March to H. Clopper (Rossouw 1952)

+ Jan Harmense Gat - Original grazing rights were granted to Jan Harmens (Tomlinson 1943)

Date unknown

^ These farms are not economically viable and the farmers generally have another property.

aerial photographs. The land use was mapped into the following categories:

i) Cultivated lands - this included all non-permanent fields such as cash crops, wheatlands, dryland plantings, fodder crops, vegetables, fallow and recently ploughed lands.

ii) Orchards and Vineyards - this included all permanent fields such as fruit orchards and vineyards.

iii) Natural vegetation

iv) Recently burnt vegetation

v) Dams

vi) Houses. The percentage area attributed to each category was calculated in km² using the technique mentioned previously. The land use trends of the farms Haumanskloof and Koelefontein were not mapped as these farms are not cultivated.

Farm owners in each of the areas were interviewed. Key Questions asked were:

History: What is the history of the farm?

Who were the previous landowners and what farming practices were used?

The history of irrigation of the farm and present irrigation practices?

Precipitation: What is the expected annual rainfall?

Have there been any years of particularly high or low rainfall? Is your district subject to severe droughts? With what frequency?

What were the effects of the floods/droughts?

Land use: What are the present land practices?

What is the value of the land for the different land uses?

Management Practices: How are the the vineyards, orchards, wheatfields and other products managed?

How much time do you spend spraying and fertilizing?

Where from and how much water is obtained for irrigation purposes?

Which crops are grown under irrigation?

Are you going to expand the existing cultivated lands?

What is the carrying capacity of your land and the present stocking rates?

Do you practice a form of rotational grazing?

Burning: Do you practice any form of veld burning?

Can you recall the occurrence of any fires and their frequency?

Soil Erosion: Are there any soil erosion problems on your farm?

Vegetation: Has there been a noticeable decline in the vegetation cover?

Have any changes occurred in the nature of the veld?

Alien vegetation: Do any alien plants occur on your farm and if so which species?

Fauna: What wild animals occur in the area?

Further information on the land use of different farms was obtained from the rural field sheets drawn up for tax evaluation

purposes in the Worcester district and Robertson districts in 1972/4 and in the Swellendam district in 1986.

3.2.2.2 Major agricultural activities in the Middle Breede River Valley

Statistical records and the Dept. of Agriculture were consulted to determine the agricultural activities and resultant products of today.

3.2.2.3 Rate of urban expansion

The rate of urban expansion was calculated for the two largest towns, Worcester and Robertson, using the past topographic maps:

(i) Worcester 3319CB - 1st ed (1954), 3rd ed (1974)

(ii) Robertson 3319DD - 1st ed (1961), 2nd ed (1974)

and 1987 aerial photographs (obtained from Dept. Surveys and Mapping, Cape Town). The areas were calculated in km² using a Digitiser as above.

3.3 RESULTS

3.3.1 Present extent of the natural vegetation and its rate of decrease

The natural vegetation between the years 1963 and 1987 decreased on average by 20 km²/yr (0.7% of the whole area/yr) to a level of 66% of the total study area in 1987. The extent of the remaining natural vegetation in 1987 is illustrated in Fig. 3.2. In 1963 the area of the natural veld was 2286.9km², in 1974 2081.8km², and in 1987 1804.7km². The extent of the natural vegetation in 1963 and 1974 was obtained directly from 1:50 000

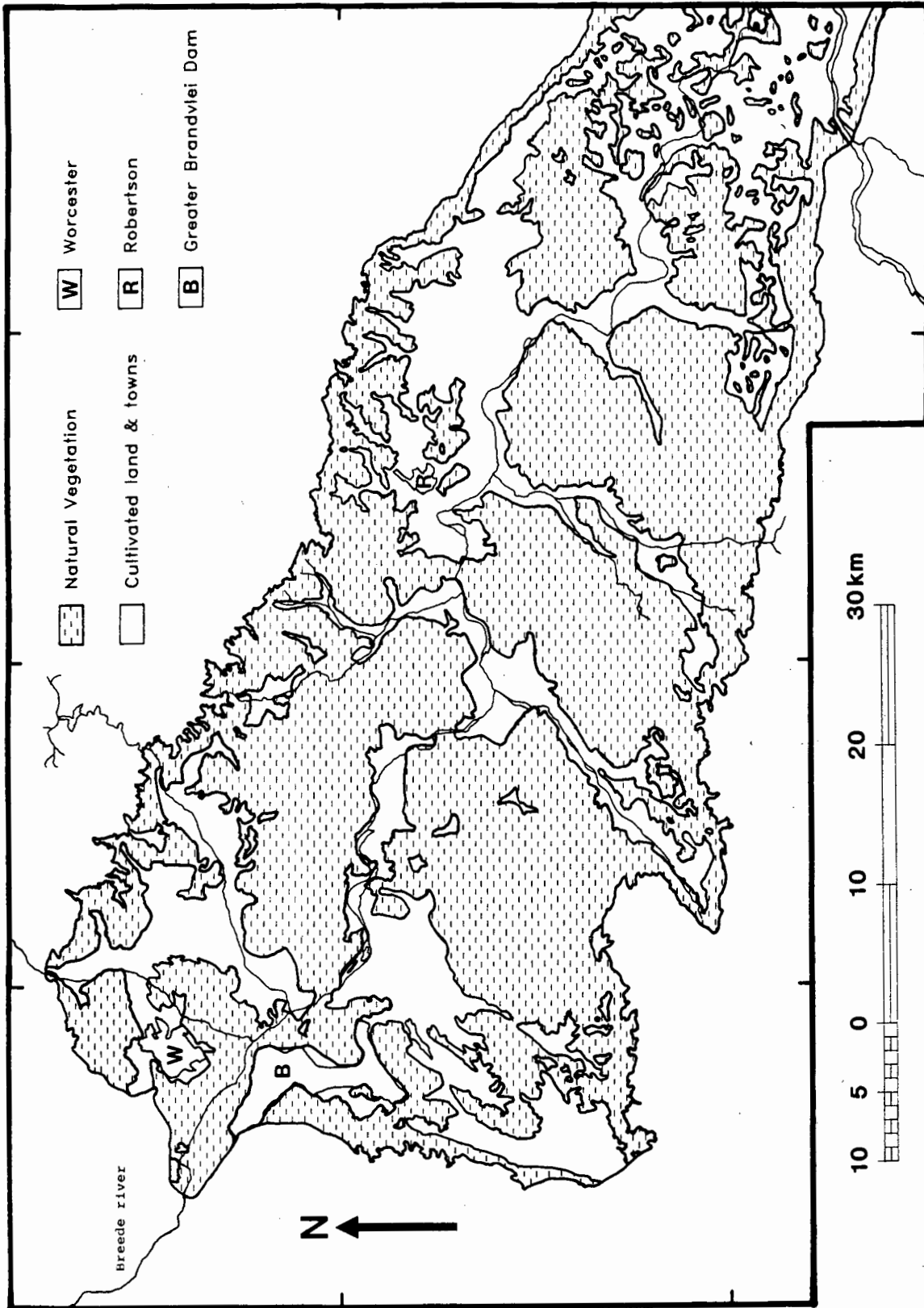


Fig. 3.2: Remaining extent of the natural vegetation of the Robertson Karoo

topographic maps which contain some error. This could have lead to an slight error in the calculation of the rate of decrease in the natural vegetation. Hence the rate of decrease in the natural vegetation (0.7% of the total study area/yr) should be regarded only as a trend.

3.3.2 Agricultural and urban expansion

In 1904 the Worcester and Robertson extension wards had population densities of less than 10 persons/km². By 1970 the density had grown to 20-39 persons/km² in Worcester and 10-19 persons/km² in Robertson (Central Statistics Service 1976a). The growth figures for the population in rural areas (Fig. 3.3a) and urban areas (Fig. 3.3b) show Worcester in particular to be a rapidly expanding region, especially in the last 10-20 years (Central Statistical Service 1976a, 1976b, 1986).

3.3.2.1 Agricultural land use trends since 1942

The results from the analysis of field sheets are presented in Table 3.2 and the information gained from the interviews is presented in Table 3.3. The decrease in the natural vegetation of each farm from 1942 is shown in Fig. 3.4, while the land use trends for each farm are shown in Fig. 3.5. Even with the use of the Bausch & Lomb Stereo Zoom Transfer Scope, a degree of distortion was unavoidable. However, this did not affect analysis of the broad trends.

3.3.2.2 Agriculture of the Middle Breede River Valley

Table 3.4 shows a summary of land use in the Worcester,

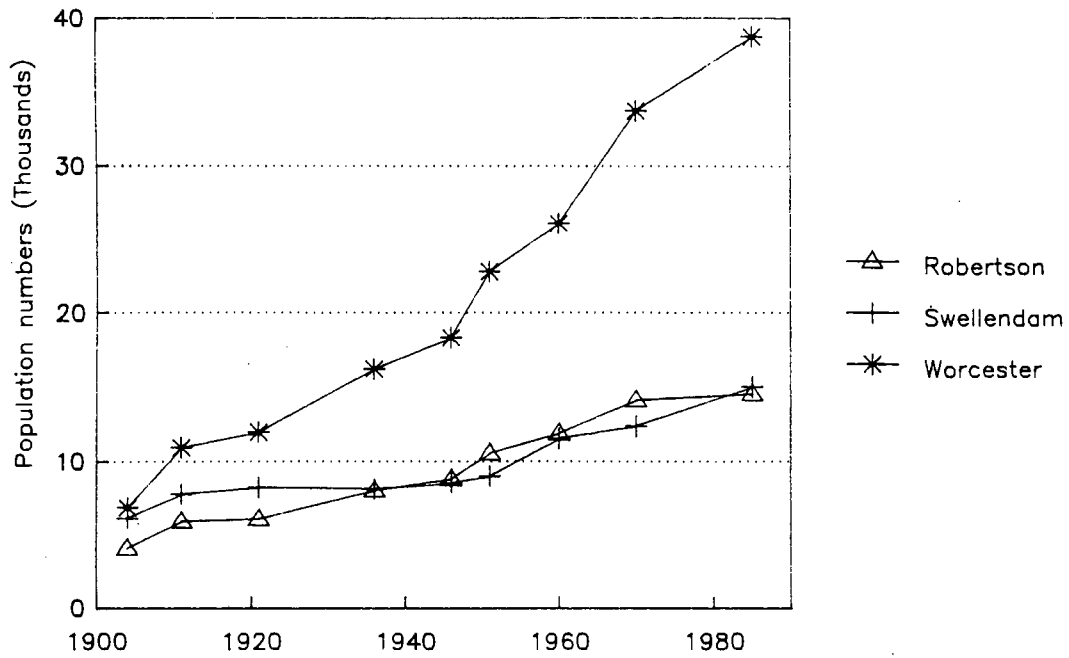


Fig. 3.3a: Population growth in the rural areas of Robertson, Worcester and Swellendam extension wards from 1904 to 1985

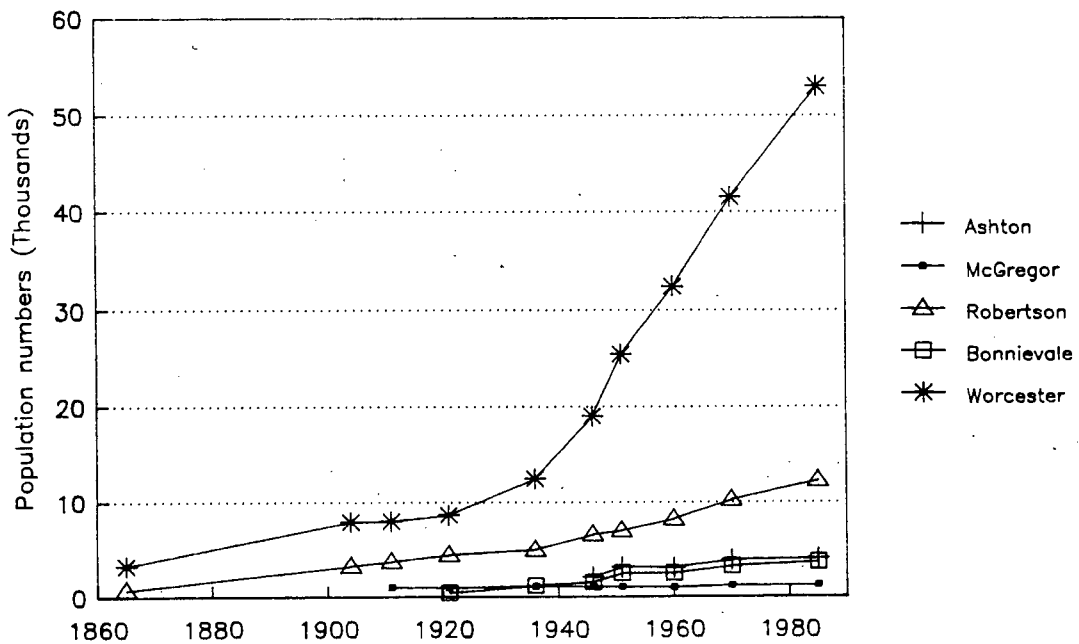


Fig. 3.3b: Population growth for the urban centres of Ashton, McGregor, Robertson, Bonnievale and Worcester from 1904 to 1985

Table 3.2: Land use of the chosen areas¹

	Aan de Doorns	Kloppersbosch	Wandsbeck	Middelburg	Haumanskloof	Koelefontein	Jan Harmens Gat
Year of evaluation	1972	1972	1972	1971	1972	1971	1986
Area of evaluation* (km²)	49	24	40	24	13	17	46
Landuse (%total area)							
Rangeland	78.17	83.72	85.48	92.09	100.00	100.00	45.79
Dryland:							
Cropland	7.83	4.12	10.41	7.04			36.04
Lucerne	0.60						3.77
Total	8.43	4.12	10.41	7.04			39.81
Irrigated land:							
Lucerne	1.03	0.99	0.40				2.20
Grazing							1.29
Vineyards	10.70	10.93	3.15				6.14
Orchard			0.53	0.87			0.43
Peaches							0.32
Apricots							0.15
Citrus							0.02
Other	1.07		0.03				2.95
Total	12.81	11.92	3.71	0.87			13.50
URBAN	0.60	0.23					0.86

* The area evaluated here was greater than the area of the farms that were mapped, as often individual farm units are evaluated together.

¹ Rural field sheets for tax evaluation purposes (Valuation Department, CDNEC)

Table 3.3: Summary of information gained from interviews

	Ran de Doorns	Kloppersbosch	Wandsbeck	Middelburg	Hauanskloof	Koelefontein	Jan Harmens Gat
Precipitation (mmpa) falls between March-Sept	293.55	255	235	218	223	190	453
History	Wine grapes have always been an important product	Wine grapes - principal source of income 100-200 sheep for own use lucerne - fodder grazing near rivers, winter grazing - veld 300 sheep - kraaled and rotated in 4 camps. supplementary feed - lucerne, fallen leaves in vineyards	This area has always supported varied landuses. wine grapes - large source of income other activities also important peaches, apricots. lucerne, sheep - 100 dutch merinos grazed on veld from May-Nov. 3 camps summer - lucerne	80 cattle - graze in 3 camps on veld: May-Nov, grain lands: Dec-May, dryland cereals	100 sheep 30 dry cows graze on veld July - August		
Farming Activity	wine grapes - principal source of income 26 milk cattle - summer grazing near rivers, winter grazing - veld 300 sheep - kraaled and rotated in 4 camps. supplementary feed - lucerne, fallen leaves in vineyards	wine grapes - principal source of income 100-200 sheep for own use lucerne - fodder	wine grapes - large source of income other activities also important peaches, apricots. lucerne, sheep - 100 dutch merinos grazed on veld from May-Nov. 3 camps summer - lucerne	80 cattle - graze in 3 camps on veld: May-Nov, grain lands: Dec-May, dryland cereals	100 sheep 30 dry cows graze on veld July - August		
Irrigation: Sources	Breede, Hex and Doorn rivers.	Keerom Dam (built in 1953) private irrigation scheme	Brandvlei Dam	La Maison	Riversplaas	Gien Oak	
Mechanism	drip, microjets, flood irrigated	microjets, sprinklers	microjets, sprinklers				
Limitations to farming	water quantity						
Fire	accidental, no deliberate burning of the vegetation						
Alien vegetation	black wattle, port jackson - drift sands, poplar, Sesbania - river banks Alien vegetation does not cover a large area ---->	Acacia - places where topsoil was eroded during flood	nil				

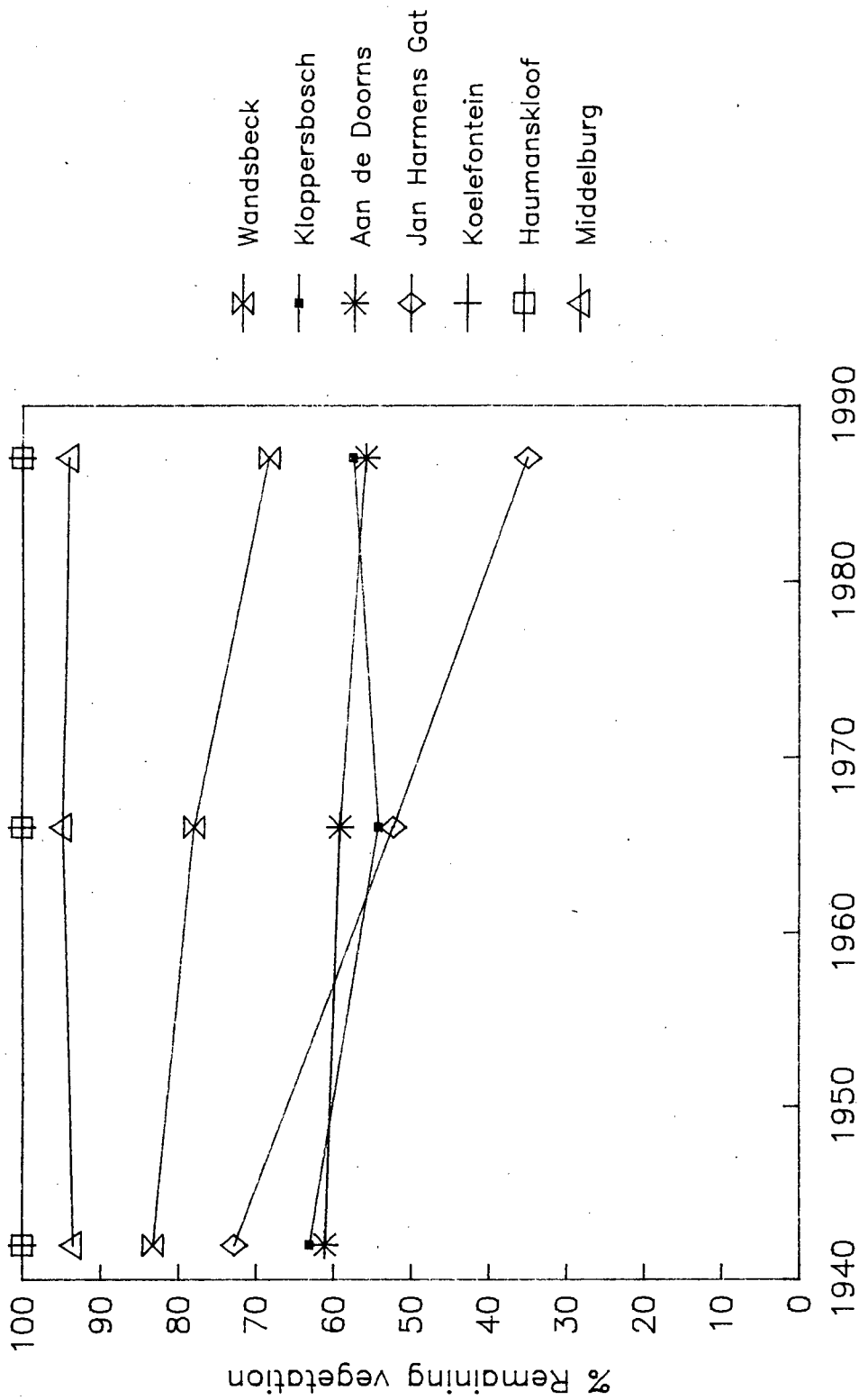


Fig. 3.4: Change in the percentage remaining vegetation in the seven areas from 1942 to 1987

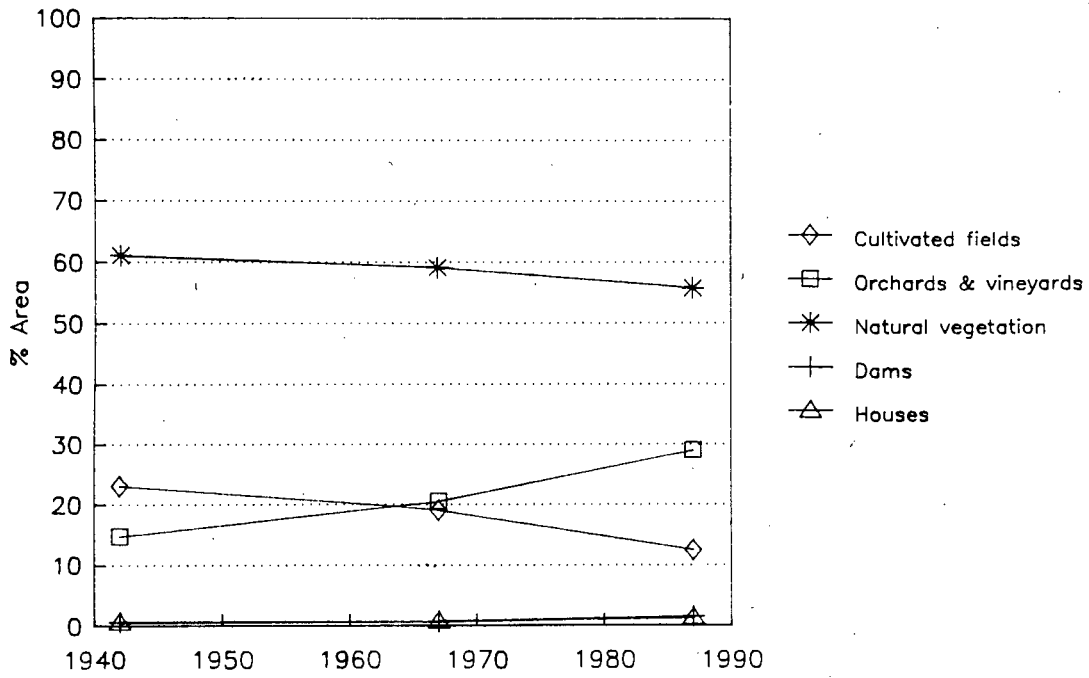


Fig. 3.5a: Land use change in Aan de Doorns from 1942 to 1987

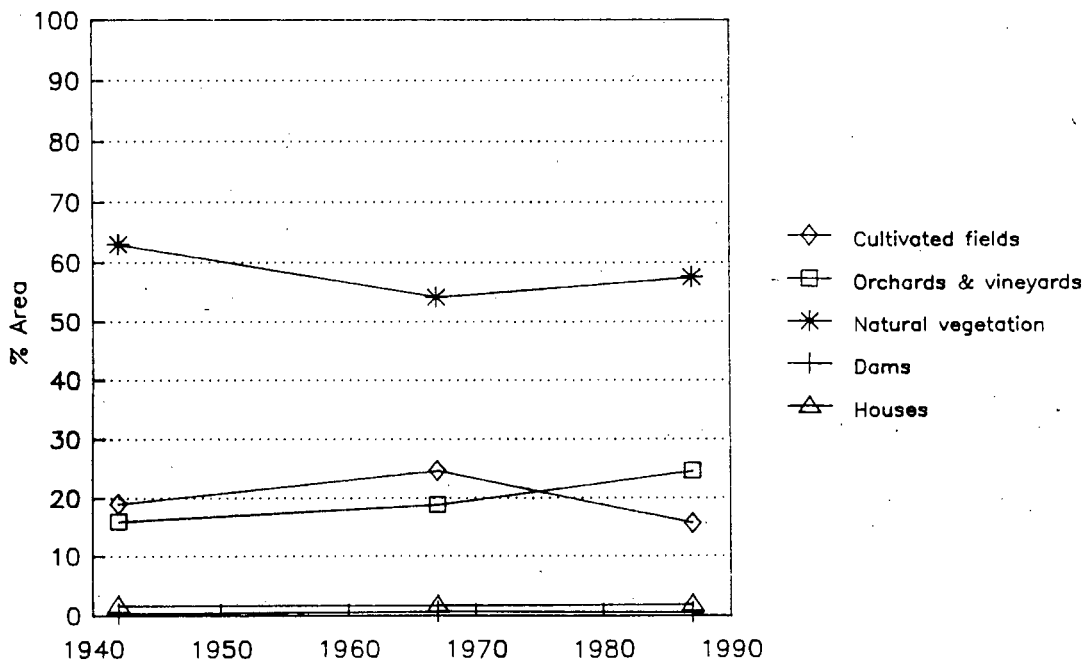


Fig. 3.5b: Land use change in Kloppersbosch from 1942 to 1987

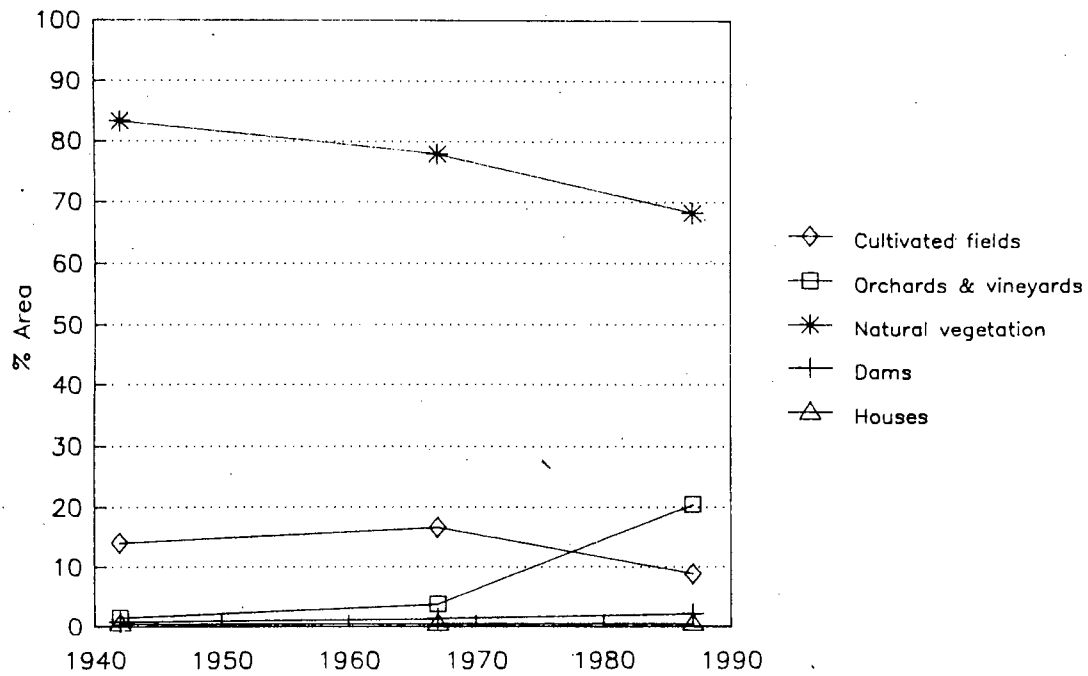


Fig. 3.5c: Land use change in Wandsbeck from 1942 to 1987

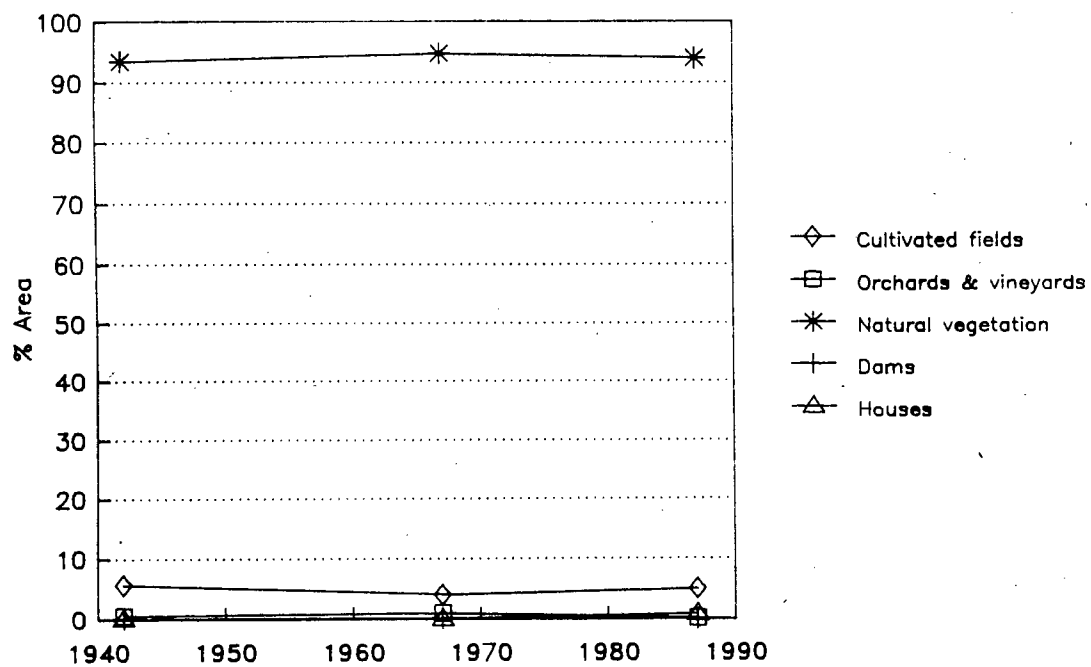


Fig. 3.5d: Land use change in Middelburg from 1942 to 1987

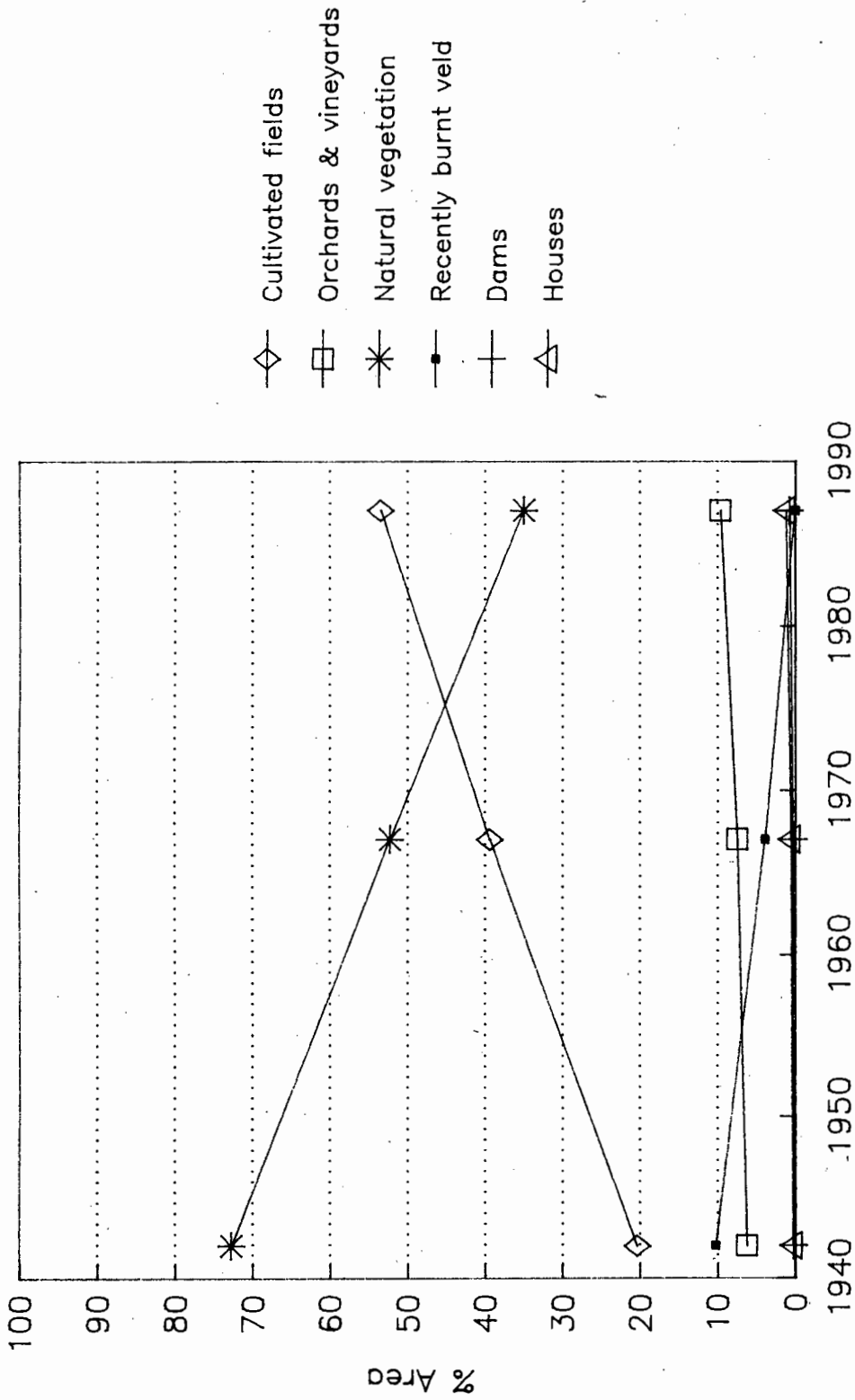


Fig. 3.5e: Land use change in Jan Harmens Gat from 1942 to 1987

Table 3.4: Land use in the Worcester, Robertson and Swellendam extension wards in 1981.
(Report No: 06-01-17, Central Statistical Service 1987)

	WORCESTER		ROBERTSON		SWELLENDAM	
TOTAL AREA (ha)	322990		1134874		340226	
%cultivated	9.92		12.11		37.12	
% of cultivated						
irrigated	72.88		81.34		7.62	
dryland	27.12		18.66		92.38	
	ha	%total area	ha	%total area	ha	%total area
PERENNIAL PLANTINGS						
orchards & vineyards						
irrigated	17765		7989		5319	
dryland	1234		240		214	
total	18999	5.88	8229	7.23	5533	1.63
fodder crops						
irrigated	2920		2282		2999	
dryland	2473		266		62002	
total	5393	1.67	2548	2.24	65001	19.11
timber & wattle plantations						
irrigated	38		55		24	
dryland	95		7		670	
total	133	0.04	62	0.05	694	0.2
ANNUAL PLANTINGS						
irrigated	2660		893		1304	
dryland	4888		2065		53789	
total	7548	2.34	2958	2.60	55093	16.19
TEMPORARY FALLOW	10797	3.34	4625	4.06	34719	10.2
NATURAL VELD	273970	84.82	93904	82.46	174122	51.18
ALL OTHER LAND	6150	1.9	1548	1.36	5064	1.49

Robertson and Swellendam extension wards (Central Statistical Service 1987), while Table 3.5 shows all the agricultural products produced in these areas in 1981 (Central Statistical Service 1987). The percentage income of the various agricultural products are illustrated in Fig. 3.6. For comparison the land use and livestock numbers of 1865 are shown for the districts of Worcester, Robertson and Swellendam (Table 3.6, Central Statistical Service 1866). (Note: The district for the different years did not encompass the same area - cf. the total area of districts in 1865 (Table 3.6) with the total area of the same region in 1981 (Table 3.4)). In 1865 only an average of 1.7% of the Robertson Karoo was cultivated, whereas by 1981 19.27% of the area was cultivated (Table 3.4 & 3.6). Because in both years the districts include mountainous regions there was a relatively low percentage of land under cultivation.

3.3.2.3 Rate of urban expansion

The town of Worcester has doubled in size since 1954 and in 1987 covered an area of 21km², whereas Robertson increased by 26% since 1962 to an area of 4km² (Fig. 3.7). In 1987 the urban areas of Worcester and Robertson covered 0.9% of the total study area.

3.4 DISCUSSION

3.4.1 Present extent of the natural vegetation

Sixty six percent of the Robertson Karoo is "remaining vegetation". This appears to be high in comparison to other lowland veld types, e.g. in west coast renosterveld McDowell

Table 3.5:

Agricultural products (area planted in ha) and numbers of livestock in the Robertson, Swellendam and Worcester extension wards. Agricultural census conducted 1981 (Report No's: 06-01-18; 06-01-19, Central Statistical Service 1987)

1) Agricultural crops-	ROBERTSON	SWELLENDAM	WORCESTER
Grain Sorghum	112	31	20
Wheat	921	36624	1651
Oats	593	7959	961
Barley	30	6088	192
Rye	5	325	15
Lupins	0	30	0
Beans	6	36	1
Dry Peas	9	22	15
Tobacco	0	8	21
Maize	0	5	6
2) Fodder & Pastoral crops-			
Total	1896	60902	4845
% of production sold	39.3	21.5	32.5
Lucerne	95	52961	285
Lucerne*	1377	2122	2171
Eragrostis curvula	0	452	90
E.curvula*	0	50	1
Teff	29.4	0	66.7
Babala	2	52	11
Babala*	17	39	87
Grass-legume mixture	0	2929	328
Grass-legume mixture*	143	218	64
Kikuya	2	49	86
Kikuya*	135	154	114
Prickly Pears	0	4	0
Salt bush	0	0	52
Other	113	1872	1506
Small grain	426	4509	1720
Tubers	0	0	10
3) Vegetables-			
Potatoes	118	243	296
Beetroot	1	4	29
Cauliflower	3	3	4
Carrots	0	3	11
Greenbeans	5	11	3
Green Peas	20	1	87
Garlick	1	2	1
Cucumbers	1	2	1
Cabbage	5	20	16
Sweet Potatoes	1	4	12
Pumpkins	10	44	38
Spanspek	2	6	14
Broccoli	0	0	10
Tomatoes	81	20	42
Onions	16	20	781
Sweetcorn & green mealies	1	3	23
Watermelons	9	3	20

4) Fruit & Nuts-

Oranges	0	61	4
Lemons	0	2	1
Almonds	1	0	3
Pecan Nuts	0	0	1
Peaches/canning	8	28	59
Peaches/canning*	712	1110	473
Peaches/fresh market	0	2	72
Peaches/fresh market*	78	43	270
Apricots/canning	5	3	30
Apricots/canning*	632	336	37
Apricots/fresh market	1	7	0
apricots/Fresh market*	20	7	8
Wine grapes	0	86	876
Wine grapes*	6232	2827	12703
Table grapes	0	0	8
Tables grapes*	17	70	3351
Grapes for drying	1	0	4
Gapes for drying*	3	22	29
Apples/canning	0	0	0
Apples/canning*	0	30	8
Apples/fesh market	0	0	3
Apples/fesh market*	2	167	17
Pears/canning	0	0	0
Pears/canning*	19	181	7
Pears/fresh market	0	0	17
Pears/fresh market*	0	79	9
Plums	0	30	2
Plums*	5	0	160
Prunes	0	0	10
Prunes*	3	16	113

* Products grown under irrigation (remaining products grown under dryland conditions).

5) Livestock nos-

Cattle:			
Mainly dairy	3194	10282	5629
Mainly beef	583	4051	2442
Woolled sheep:			
Karakul	396	10239	95
Merino	2312	267733	15197
Meat merino	4476	27257	5406
Other	2412	12485	8704
Non-woolled sheep:			
Dorper	2883	20810	15876
Blackheaded Persian	70	2	23

Other	1150	4741	1500
Goats:			
Angora	361	0	4
Other	2220	1762	695
Pigs	3851	3909	10776
Horses	723	441	532
Mules	9	10	32
Donkeys	9	28	62
Poultry:			
Chickens	151792	6524	118704
Turkeys	38	126	94
Ostriches	120	231	86

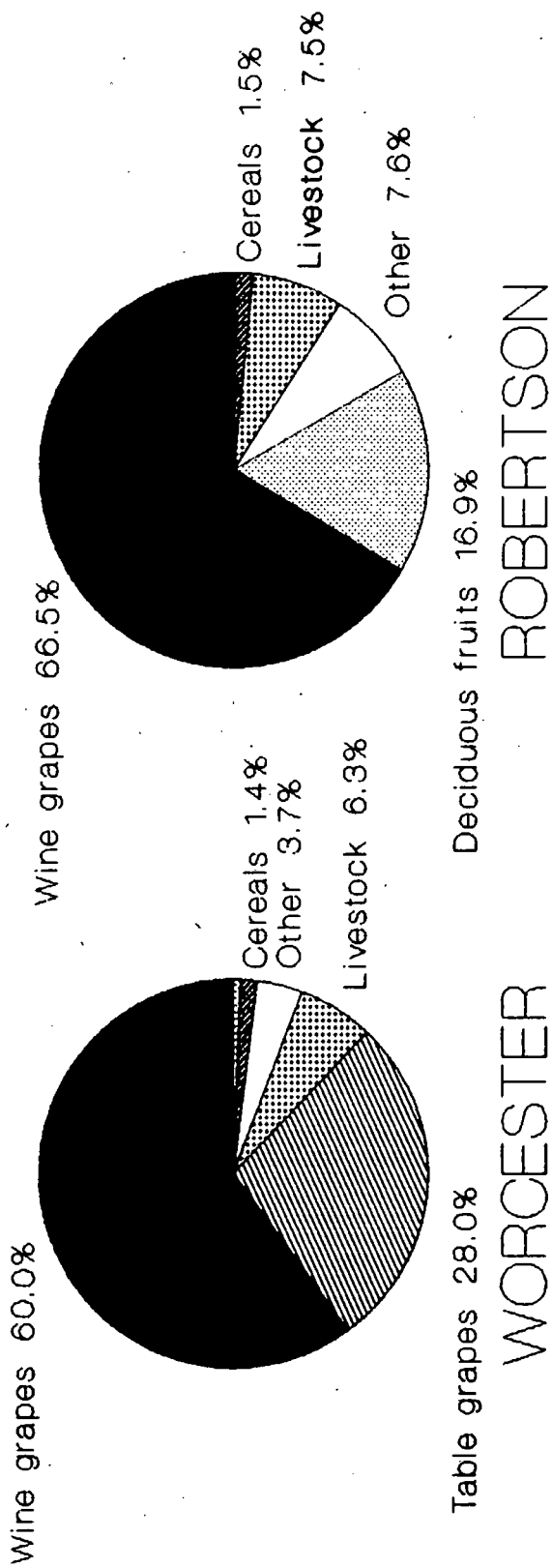


Fig. 3.6: Percentage gross income derived from different agricultural products in the Worcester and Robertson extension wards (Kriel et al. 1979, Van der Merwe et al. 1980)

Table 3.6: Agricultural products and livestock numbers in Worcester, Robertson and Swellendam districts in 1865.
(Central Statistical Service 1866)

	WORCESTER		ROBERTSON		SWELLENDAM	
Total area	441260.9		196721.2		390720.3	
% cultivated	1		2.4		1.8	
	ha	%Total area	ha	%total area	ha	%total area
Wheat	1349.7	0.31	2065.5	1.05	2886.5	0.74
Barley	530.9	0.12	633.8	0.32	1884.6	0.48
Rye	495.5	0.11	244.5	0.12	188	0.05
Oats	350.7	0.08	268.5	0.14	1779.9	0.46
Maize	65.4	0.01	91.2	0.05	42	0.01
Peas, Beans & Lentils	163.6	0.04	518.8	0.26	97	0.02
Tobacco	8.9	0.002	41.6	0.02	37.7	0.01
Potatoes/Gardens	215.3	0.05	345.2	0.18	122.9	0.03
Orchards/Orangeries	785.8	0.18	124.1	0.06	81.8	0.02
Vines	457.1	0.10	369.6	0.19	65.3	0.02
		1.00		2.39		1.84
Livestock nos:						
Horses	3708		2141		4995	
Mules/Asses	363		712		996	
Cattle	11610		7398		11343	
Sheep-						
Woolled	48075		19281		250586	
Cape	43636		6963		1364	
Goats-						
Angora	235		514		3928	
Other	33869		55668		55300	
Pigs	3183		2650		3392	
Ostriches	49		0		0	

*In 1865 Robertson district included the area surrounding Montagu.

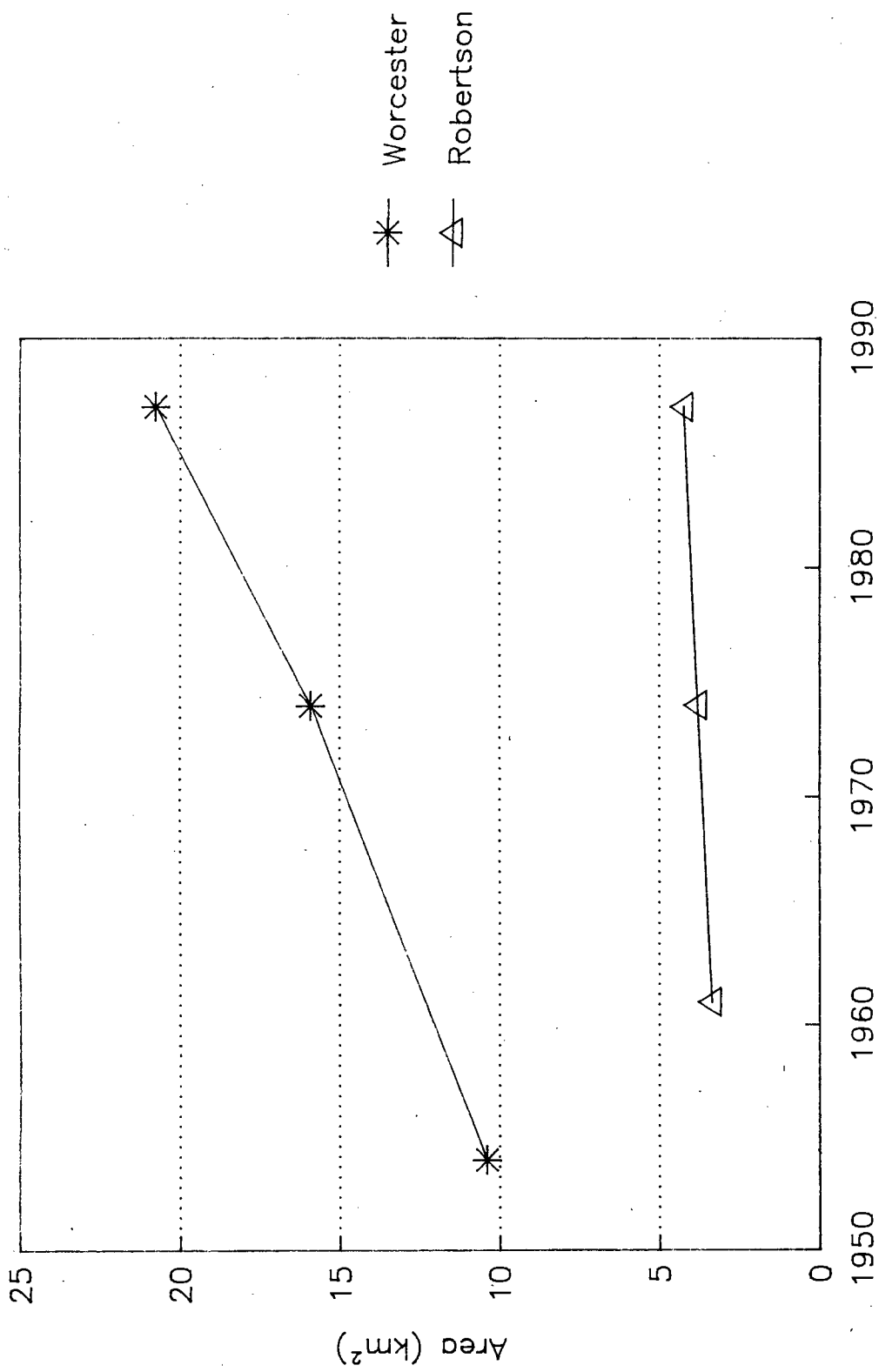


Fig. 3.7: Urban expansion in Worcester and Robertson

(1988) estimated the extent of remaining vegetation to be only 3%. However, certain communities in the Robertson Karoo are selectively cultivated above others, i.e. the natural vegetation appears to have been selectively cleared along the rivers and along the eastern boundary of the study area (Fig. 3.2). It is these communities which are severely threatened. This selective cultivation of agricultural lands has been documented before in other areas (Macdonald 1989, McDowell 1988).

3.4.2 Agricultural and urban expansion

3.4.2.1 Agriculture

a) Decrease in the natural vegetation of the Robertson Karoo -

There has been a rapid decrease in the extent of the natural vegetation, primarily as a result of Agricultural expansion. In 1865 the major agricultural activity was livestock farming and cultivated land played a minor role (only 1.7% was cultivated, Table 3.6, see Chapter 2). Today a larger percentage of the area is under cultivated land and livestock appears to play a smaller role in the income of the farmers (Fig. 3.6). Even so, total livestock numbers have increased, illustrating the growing pressures on the land. Population growth figures show the increase in population in the Worcester, Robertson and Swellendam extension wards (Fig. 3.3a), further demonstrating the pressures on the available land. This increase in population appears to be especially rapid in the extension ward of Worcester over the last 10-20 years.

Fig 3.5 shows that natural vegetation of both Aan de Doorns and Kloppersbosch has decreased only by 6% of the total area from 1942 to 1987. These areas, which occur on the banks of the Breede and Nuy Rivers respectively (Fig. 3.1), had the highest percentage of cultivated land in 1942 (Fig. 3.5) and also appear to be the earlier settled areas (Table 3.1). Finding the Robertson Karoo so dry, the early farmers settled along the rivers, selectively cultivating these areas; and as already noted above, this continues today.

Although Wandsbeck is situated on the banks of the Poesjenelsrivier (Fig. 3.1), this area was not cultivated to the same extent in 1942 as Aan de Doorns and Kloppersbosch. Even so, the extent of the natural vegetation decreased from 83.25% to 68.17% of the total area (a decrease of 15%) during the years studied (Fig. 3.5).

It appears that in 1942 the Poesjenelsrivier did not provide enough water for irrigation and hence cultivation of the land. The area under orchards and vineyards increased dramatically (Fig. 3.4c) between 1967 and 1987 with a corresponding decrease in the natural vegetation (Fig. 3.4 & 3.5c). This increase relates to the construction of Brandvlei Dam in 1970 (Schreüder *et al.* 1988), which is the major source of water for irrigation today (Table 3.3).

Farms situated along rivers, as those described above, automatically have a right under Roman Dutch Law to water and

are only required to pay for the cost of water if a government scheme supplies the water to a more convenient place than the official outlet pipe. This is not the case with the following farms.

At Koelefontein, Haumanskloof and Middelburg, situated in the Worcester and Robertson districts away from the major rivers (Fig. 3.1) there was little or no transformation of the natural vegetation to cultivated fields. These farms have to pay for the water right as well as the cost of transportation of the water (H. Luttig pers. comm.). In addition, the Department Water Affairs will only provide water if the scheme will benefit a minimum of ten farms (H. Luttig pers. comm.). The agricultural potential of these farms is dependent on the future availability of water. Fig. 3.5d shows the limited agricultural development of Middelburg which is situated away from a major river. (Fig. 3.1 does show a river flowing through Middelburg, however this river is seasonal providing a minimal volume of water for irrigation).

The above discussion indicates that water is of vital importance for the growth of vineyards and orchards and the cultivation of crops in the Worcester and Robertson districts in which the majority of the area falls. In fact in the Worcester and Robertson extension wards, an average of 82.63% (92.38% - Worcester and 72.88% - Robertson, Table 3.4) of the cultivated lands are under irrigation. Agricultural expansion is therefore

limited by the available water in these areas.

Jan Harmens Gat, situated in the Swellendam extension ward, shows the greatest decrease in natural vegetation. This area is situated in the east of the study area and receives a higher rainfall ($>400\text{mm yr}^{-1}$, see Fig. 4.4 resulting in the cultivated fields being grown under dryland conditions). In the east of the study area (Swellendam extension ward) 81.34% of the cultivated lands are grown under dryland conditions showing that in these regions agricultural expansion is not limited by the available water (Table 3.4).

b) Agricultural products of the Middle Breede River Valley -

The cultivation of non-permanent crops in Wandsbeck decreased from 1942 to 1987 and these have been replaced almost entirely by orchards and vineyards (Fig. 3.5c). This trend seems also to be visible in Aan de Doorns and Kloppersbosch (Fig. 3.5a & b). In discussion with landowners (Table 3.3) and assessment of evaluation forms (Table 3.2) it was found that wine grapes are now the most important agricultural product, especially in Aan de Doorns and Kloppersbosch. In Wandsbeck wine grapes are important, although peaches and apricots are also grown (Table 3.2 & Table 3.3).

In all these farms, livestock are also kept, although in small numbers. In Kloppersbosch only enough sheep are kept for the owner's personal use, whereas in both Aan de Doorns and Wandsbeck sheep and cattle contribute to the income of the

farms. These animals are grazed on the natural vegetation in winter and either given supplementary feed in summer or grazed on planted pastures. In the winter, on some farms the sheep are also given supplementary feed (Table 3.3). These farmers did not appear interested in the carrying capacity of the natural vegetation and had not investigated veld improvement options. This is due to the fact that livestock farming does not provide a sufficient economic return. In discussion with agricultural experts in the area (N. de Jager, H. de Wet pers. comm.) it became apparent that livestock farming is not a major agricultural activity and the majority of livestock, especially the dairy cows, are grazed on planted pastures.

In Koelefontein, Haumanskloof and Middelburg, the natural vegetation is utilized as rangeland and grazed by cattle, sheep and ostriches. Again the farmers are not interested in the carrying capacity of the vegetation. The income gained from these livestock is not considered important and all these farmers had additional farms situated on rivers where the most important agricultural activity was wine grapes (Table 3.3). An example is Middelburg, which was bought by its present owner in 1983 as an investment for the future when water becomes available for irrigation (P. du Toit pers. comm.).

In general, for the Worcester and Robertson extension wards, which comprise the greater proportion of the study area, the income from agricultural products is greatest for wine grapes (Fig. 3.6). Deciduous fruits, livestock, cereals and vegetables

are other agricultural products which contribute additional income (Table 3.5).

At the farms in the area of Jan Harmens Gat, situated on the eastern boundary of the study area, the products are predominantly wheat, barley and sheep (Table 3.2). Vineyards are restricted to areas of deeper soils (60-80cm deep, this latter fact is responsible for the eastern limit of the vineyards in the valley as the soils in the Swellendam area are shallow - <30 cm deep, J. van Zyl pers. comm.). Wheat and barley lands are restricted to areas of deeper soils. The only areas of remaining natural vegetation are found on the summits of koppies, where the soils are too shallow for cultivation (<2-3cm, Mr. Koussiman pers. comm.). The sheep, usually meat merino, graze on the natural vegetation for limited periods of the year. The grazing value of the natural vegetation is regarded by the Department of Agriculture as uneconomical for the purpose of rangeland. The carrying capacity in the east of the study area is, however, higher (1 small stock unit to 4-5ha; Mr. Koussiman, pers. comm.) than in the Worcester and Robertson districts (1 small stock unit to 8ha, B. Bayer pers. comm.)

In conclusion, the most important agricultural products are wine grapes and wheat which both cause the total destruction of the natural vegetation. A study of the aerial photographs of the areas revealed very few non-permanent and no permanent fields to lie fallow. In fact Kloppersbosch was the only area where the

extent of the natural vegetation increased slightly from 1967 to 1987 (Fig. 3.4) as a result of certain non-permanent fields lying fallow. The above suggests that agricultural expansion in this area usually results in the irreversible destruction of the natural vegetation.

c) Agricultural expansion and the future -

It should be noted that there is plentiful irrigable land remaining for future agricultural expansion (survey conducted in 1978; Schreüder *et al.* 1988). But, agricultural expansion is limited by the availability water in the Worcester and Robertson districts. Thus agricultural expansion is dependent on:

i) cost of water

Until now the Worcester/Robertson valley has received water as a basic provincial right, farmers only paying a few cents per kilolitre for the privilege (H. Luttig pers. comm.). With the cost of the expansion of the Greater Brandvlei Dam, the price of additional water has increased a hundredfold (H. Luttig pers. comm.). At present the dam is 42% full from natural inflow from the Smalblaar and Holsloot Rivers (Schreüder *et al.* 1988). If the demand for water increases, a pump scheme from the Breede River will further increase the capacity of the dam which, in turn, will further raise the price. With the present poor economy and low prices for crops, the cost of irrigating a field is uneconomical (N. de Jager, H. Luttig, J. Piaget pers. comm.).

ii) Market

Even if the water were free, there would be a problem with selecting a suitable crop to plant, since most of the area's agricultural products such as wine, peaches, apricots and wheat, are in oversupply. Thus, at present there is a trend to find alternative agricultural products (H. de Wet, N. de Jager pers. comm.).

Although growing vegetables may appear on the surface to be a suitable line of action, the market for them is relatively unstable compared with that for wine grapes and canning peaches and are therefore less attractive to farmers (H. de Wet pers. comm.). In the light of this agricultural officers in the area (H. de Wet, N. de Jager pers. comm.) advise farmers not to expand their existing agricultural lands, but to concentrate on increasing unit production per ha or per allocated water.

It is concluded from this that it is not the water *per se* which limits cultivation, but the cost of water and the market for agricultural products grown in the Worcester and Robertson districts.

In the east of the study area, agricultural expansion is limited to areas of deeper soils and the technology has not as yet been developed to plough the areas of remaining natural vegetation. These farms have also been affected by the oversupply of wheat and the majority of the cultivated lands are at present under barley.

Agricultural expansion at present does not appear to pose any great immediate threat to the remnant vegetation. However, if the situation changes, the remaining low-lying areas of high agricultural potential will be cleared. The expansion of agricultural fields is determined by the prevailing agro-technology and economic conditions. If these suddenly change, virgin land will be ploughed up. Agricultural expansion could be depicted by a series of steps controlled by sudden changes in the various limiting factors, e.g. the economic conditions, water availability and the agro-technology. The latter factor, e.g. new concepts in ploughing, erosion prevention, fertilizers and their application, farm machinery design and crop breeding techniques, would result in the cultivation of marginal and non-arable lands previously considered unsuitable for cultivation (McDowell 1988).

d) Importance of fire -

The farms in the Worcester and Robertson districts are situated in the karroid veld and ecotonal zones where fire does not appear to be an important ecological factor (Table 3.3). In general, veld burning is not a feature of Karoo vegetation (see Chapter 2).

The farms on the eastern boundary of the map showed the only evidence of veld burning (Fig. 3.5e).and the incidence of it appears to have been drastically reduced since 1942. According

to Koussiman (pers. comm.), veld burning today is controlled and farmers are allowed to burn only every 5-8 years.

3.4.2.2 Urban expansion

The municipal areas cover less than 5% of the study area, indicating that they pose a small threat. However, the population of the Middle Breede River valley is growing rapidly (Figs. 3.3a & b). The urban area with the greatest population is Worcester followed by Robertson, Ashton, Bonnievale, McGregor and Drew (Fig. 3.3b). The extent of the urban area of Worcester, has increased in the last 13 years (Fig. 3.7). The flora around Worcester is very diverse as a result of the complex geology and at least 13 threatened species occur there (see Chapter 5). The areas under greatest threat are those within the municipal boundaries of Worcester.

Urbanization in general may play an increasingly important role. There are plentiful underground water reserves in the Worcester/Robertson area, but water quality is low and too saline for agricultural purposes. However, this water is adequate for urban development. Worcester, and in fact the whole of the middle Breede River valley, is highly suitable for urban development (B. Gasson pers. comm.), because there is plentiful water and the valley is situated 100 km from Cape Town. In addition, urban development of the middle Breede River valley would perhaps help to alleviate the pressure on the Cape Peninsula (B. Gasson pers. comm.).

3.4.3 Other potential threats

Aliens infestations are not common in the Karoo vegetation apart from along rivers where *Sesbania* and *Acacia* infestation are a concern (Table 3.3).

Another potential threat is mining. Although mining is very localized, it selectively threatens those plant communities growing on a substrate which has the economic potential to be mined. At present there is a lime quarry at Langevlei, NW of Robertson. At least 4 rare species occur in this area (see section 5.3.2). In addition, there is a large quarry at Brewelskloof, north of Worcester.

3.5 CONCLUSIONS

On the basis of the areas studied, the farms in the Robertson Karoo can be divided into three categories with the following characteristics:

1) Farms with a high percentage of land under vineyards and orchards.

These are located on a river. Livestock farming is regarded as a minor source of income. The livestock present, however, are generally not grazed on the natural veld continuously and either receive additional fodder or they are grazed on planted pastures. The natural veld is generally under-utilized. e.g. Aan de Doorns, Kloppersbosch and Wandsbeck (Fig. 3.5a, b & c).

2) Farms with little or no land under cultivation.

These areas are situated at a distance from rivers. Furthermore these farms do not yield a high income for the owners, who in all three cases own additional farms located on a river. e.g. Middelburg, Koelefontein and Haumanskloof (Fig. 3.5d).

On these farms the available water is a limiting factor for future agricultural expansion.

3) Areas situated on the eastern boundary of the study area, situated mainly in Renosterveld.

A high percentage of the area is under dryland cereals. Livestock are of importance although they mainly graze on planted pastures. The cultivated lands are limited to areas of deeper soils. e.g. Jan Harmens Gat (Fig. 3.5e).

The above shows that the major threat, i.e. the expansion of cultivated lands, generally involves total and often irreversible destruction of the natural vegetation. At present, with the high price of irrigable water and a poor market for products, agricultural expansion is less of a threat than previously. This situation is volatile and could change at any time, thus such expansion remains a serious threat.

Alien infestations are severe only along the rivers and the vegetation of the majority of the remaining low lying river flats has been severely reduced. Fire is not an important feature across much of the Robertson Karoo. Urbanisation and to

a lesser extent mining are important localized threats.

Conservation measures require that urgent attention be focused on habitats which are immediately threatened:

- i) The low lying vegetation surrounding Worcester
- ii) The remaining low lying flats and the areas of high agriculture potential (see Chapter 4).
- iii) Low lying river flats which are threatened by alien infestations.
- iv) Communities growing on a substrate which has the economic potential to be mined.

Chapter 4 which follows provides a quantitative assessment of the largest threat to the remaining natural vegetation, i.e. agriculture.

CHAPTER 4: THE CALCULATION OF
AGRICULTURAL THREAT INDICES FOR THE
ROBERTSON KAROO

4.1 INTRODUCTION

As acknowledged in Chapter 3, agriculture is the largest threat to the continued existence of the Robertson Karoo. Although large scale agricultural expansion is regarded as currently unlikely, it is nevertheless important, as an aid to future conservation planning, to identify those areas which have a high agricultural potential and are thus threatened by future agricultural expansion.

It is well known that some areas are more "arable" (more suitable for a particular agricultural activity) than others. Bennett (1958) noted that the progress or decline of nations and civilizations is linked to the vital factor of "good land" availability. Scotney (1971) suggested that soils provide the only reliable basis for developing a land capability (land potential) classification. Soil texture, depth and, to a lesser extent, nutrients form the basis of the agricultural potential of a certain area. Although modern fertilizers can compensate for nutrient deficiencies, fertilizing is an additional expense.

Precipitation and slope gradient are additional physical constraints in the cultivation of new lands (Scotney 1971). In the absence of the necessary precipitation, water must be available for irrigation. Irrigation is not always feasible as it increases the cost of managing a particular cultivated area. Steep gradients are also unfavourable, as they are susceptible to soil erosion (McDowell 1988) and generally have shallow soils. Added to this, is the physical difficulty of ploughing

steep slopes.

It was decided that a numerical measurement of the agricultural potentials (or threats) in the study area could be derived using the above-mentioned physical constraints, i.e. soil quality, slope gradient and precipitation measurements. These agricultural threat indices, worked out for the entire study area, will then be tested to see how they can predict future agricultural expansion.

4.2 MATERIALS AND METHODS

Before the procedures used are documented, the rationale behind the methodology is discussed.

4.2.1 Discussion of rationale

To derive agricultural threat indices for the Robertson Karoo, it is necessary to divide the area into a number of units. The smaller the units, the higher the number and therefore the greater the resolution obtained in predicting the likelihood of clearance for agriculture. The most obvious characteristic on which the divisions should be based, since conservation of the natural vegetation is the ultimate aim, is the different vegetation types.

The only comprehensive vegetation survey conducted in the Robertson Karoo was Joubert's work (1968, see section 1.4.5). Whilst this survey provided an overview of the vegetation,

dividing it into eight communities, it did not show the enormous variations occurring within these communities. An example of this is the distinctly different species compositions at Worcester Veld Reserve and Vrolijkheid Nature Reserve (personal observations), although both these areas occur in the vegetation communities described by Joubert (1968) as *Euphorbia mauritanica* and *Pteronia paniculata* communities. Researchers (B. Bayer, C. Burgers pers. comm.) concluded that Joubert's (1968) communities were too broad for developing a conservation strategy.

It would seem that the solution to this would be simply to generate a contemporary, natural vegetation map with the required detail and use this in the division of the study area. However producing such a map would be unfeasible because of the amount of time and field work necessary. Therefore a quick, yet reliable method of classifying the vegetation of the Robertson Karoo needed to be found.

Such a method would be to classify the vegetation using environmental constraints since :

- 1) plants are indicators of the conditions under which they grow, they can serve as an index for soil and climate (Jarman et al. 1983). Considering the reverse may also yield predictions about plant communities, viz: if one considers the edaphic and climatic nature of an area it may be possible to predict what type of plant community naturally occurs there.
- 2) these environmental conditions can be used to divide the

entire study area into "natural area units". Agricultural threat indices can be calculated for each unit and it would then be possible to test statistically the percentage of remaining vegetation in each unit against its corresponding agricultural threat index. This would establish if the indices correlate with past agricultural clearance in a particular unit, and therefore if they could be used to predict the likelihood of future agricultural expansion.

It was decided to use this method, and the first step was to determine the environmental constraints likely to be important in the natural vegetation patterns of the Robertson Karoo. Karroid ecosystems are characterized by low annual rainfall (Hoffman & Cowling 1987), whereas fynbos, excluding renosterveld, is characterized by a higher rainfall. In this region a mean annual precipitation of above 600mm will indicate the prevalence of fynbos communities (Campbell 1985). However, geology is also recognized as an important determinant of vegetation type in the winter rainfall region (Bayer 1984, Moll & Bossi 1984), whereas at the microscale, different soils are associated with distinct floral associations. Bayer (1984) noted that geology, and hence soil, overrides all the other ecological factors which operate in determining vegetation composition in the winter rainfall region. Stebbins (1952) noted that in more arid regions (such as the Robertson Karoo), local diversity in topography, soil, etc. has a relatively greater effect on the character and composition of the vegetation than in more mesic

regions.

After consulting the available relevant literature (Bayer 1984, McDowell 1988, Moll & Bossi 1984, Stebbins 1952, Thwaites & Cowling 1988) and in discussion with various researchers (C. McDowell, B. Bayer pers. comm.), geology and soil were determined as being the principal factors delimiting particular floral associations in the Robertson Karoo. In addition, because the geology and soil of the area are highly diverse, the units derived from these parameters would be small enough to separate out the different aspects of slope etc. Therefore it was decided to base the divisions on areas of different geology and soil. Finally, for greater resolution, the critical 600mm precipitation isohyet was used to divide Fynbos (>600mm) from Karoo and Renosterveld (<600mm).

4.2.2 Procedure

Four procedures were followed:

- a) Division of the entire Robertson Karoo into cohesive "natural area units" on the basis of geology, soil and precipitation
- b) Derivation of agricultural threat indices for each of the "natural area units" using soil quality, slope gradient and precipitation as parameters
- c) Determination of the remaining natural vegetation in each unit
- d) Statistical analysis of the effectiveness of the indices in predicting the likelihood of each area's clearance for agriculture

4.2.2.1 Environmental information

To achieve the above it was necessary to obtain relevant environmental information. Thus, 1:250 000 geology, soil, relief and precipitation maps were obtained for the study area (see Figs 4.1, 4.2, 4.3, 4.4 respectively).

a) Geology

The geology map was obtained from :

(i) An unpublished report which covers the study area west of 20°E (Greeff 1978).

(ii) The remaining area east of 20° was obtained from the unpublished 1:250 000 geological maps of Ladismith and Riversdale produced by Geological Survey, Bellville.

b) Soil

The soil map was drawn using information obtained from the Soils and Irrigation Research Institute, Elsenburg:

(i) 1:250 000 soil association map of the Breede River valley compiled by F.Ellis, B.H.A. Schloms, R.B. Rudman and A.B. Oosthuizen, Map nr. 12042 (1979).

(ii) 1:250 000 Riversdale and Ladismith unpublished soil maps compiled by F. Ellis and B.H.A. Schloms.

c) Relief (i.e. slope gradient)

The relief map was drawn from the following topographic maps:

(i) 1:250 000 - 3319 Worcester (3rd ed.; 1980)

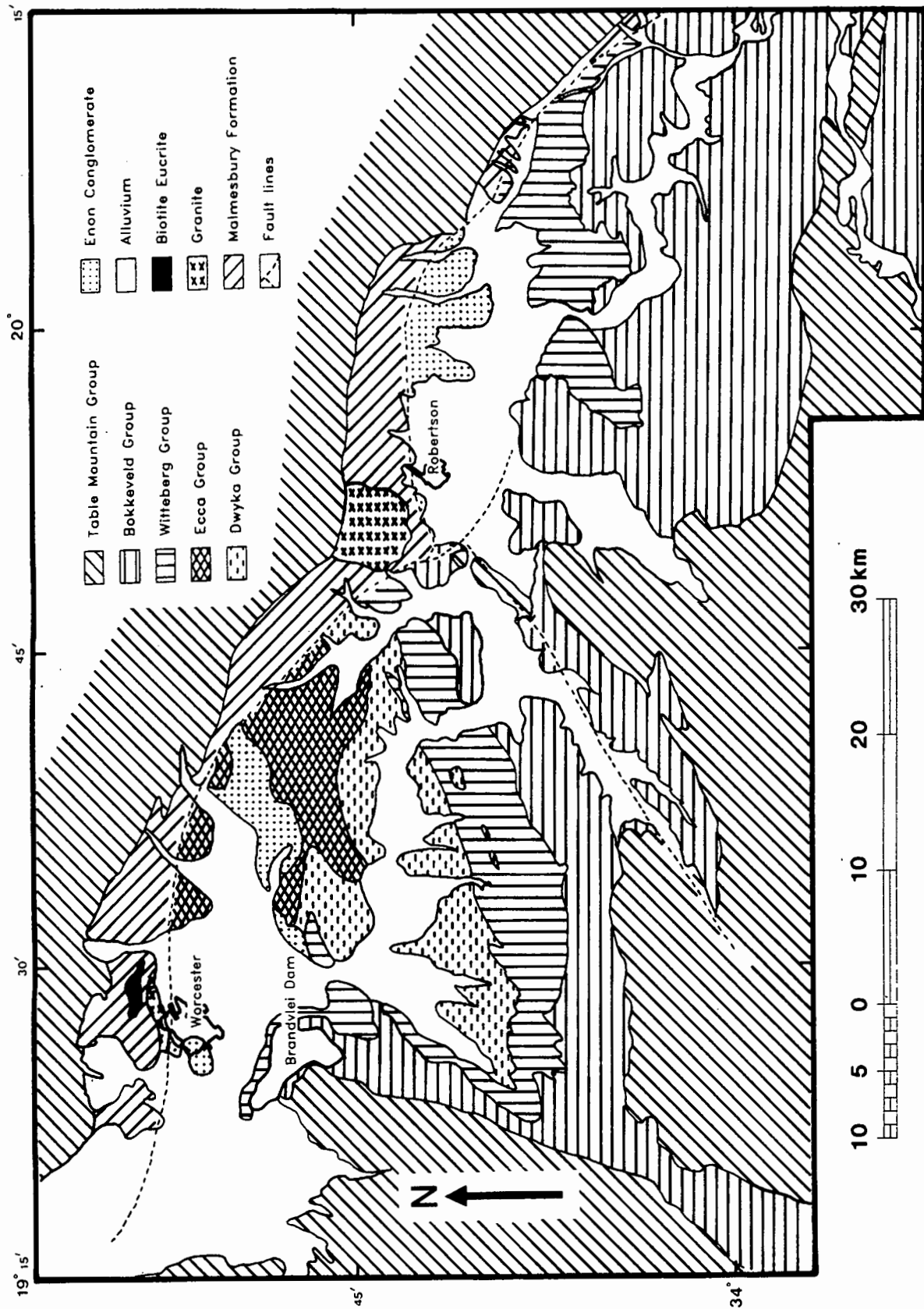


Fig. 4.1: Geological features of the Middle Breede River Valley

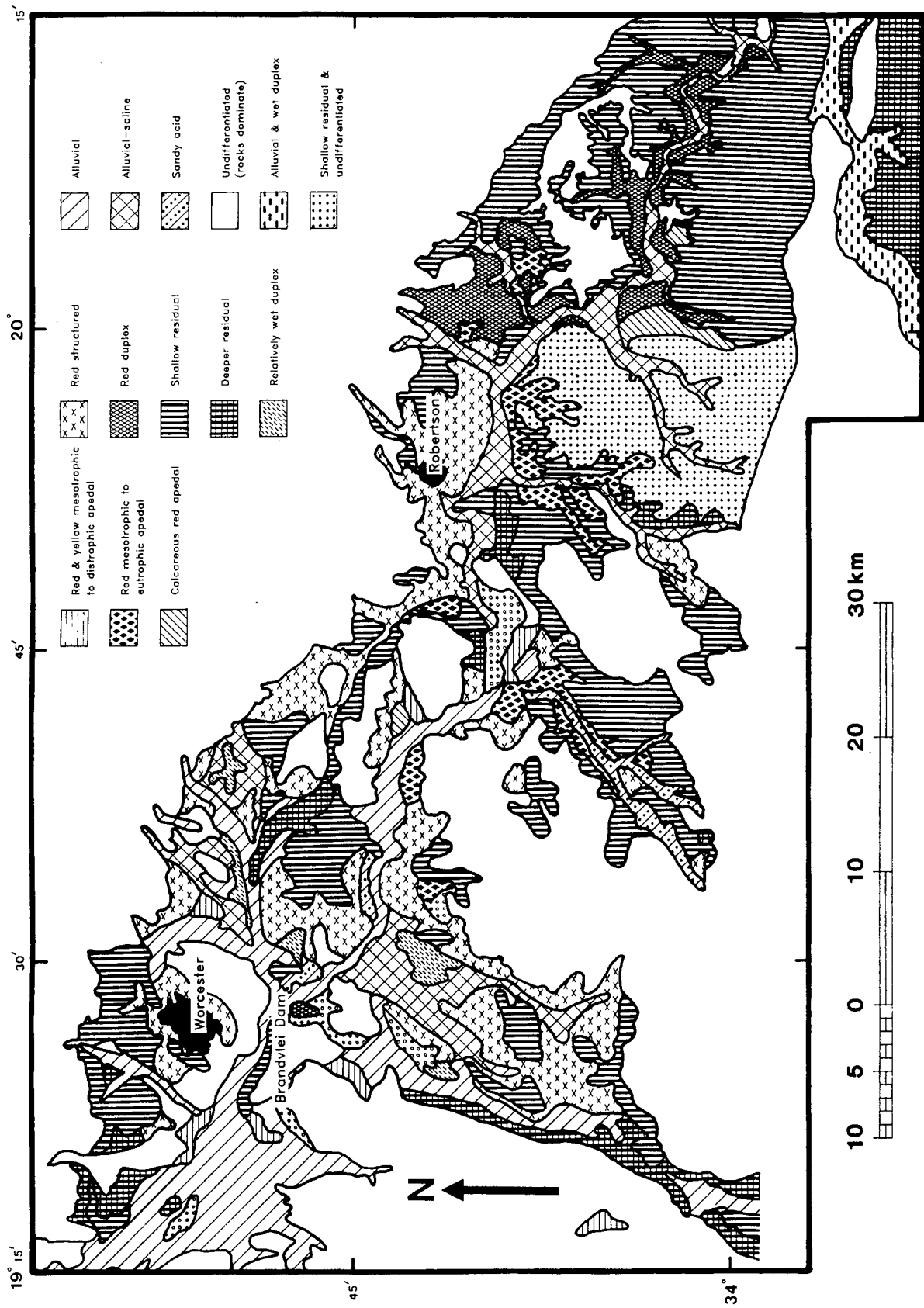


Fig. 4.2: Soil associations of the Middle Breede River Valley

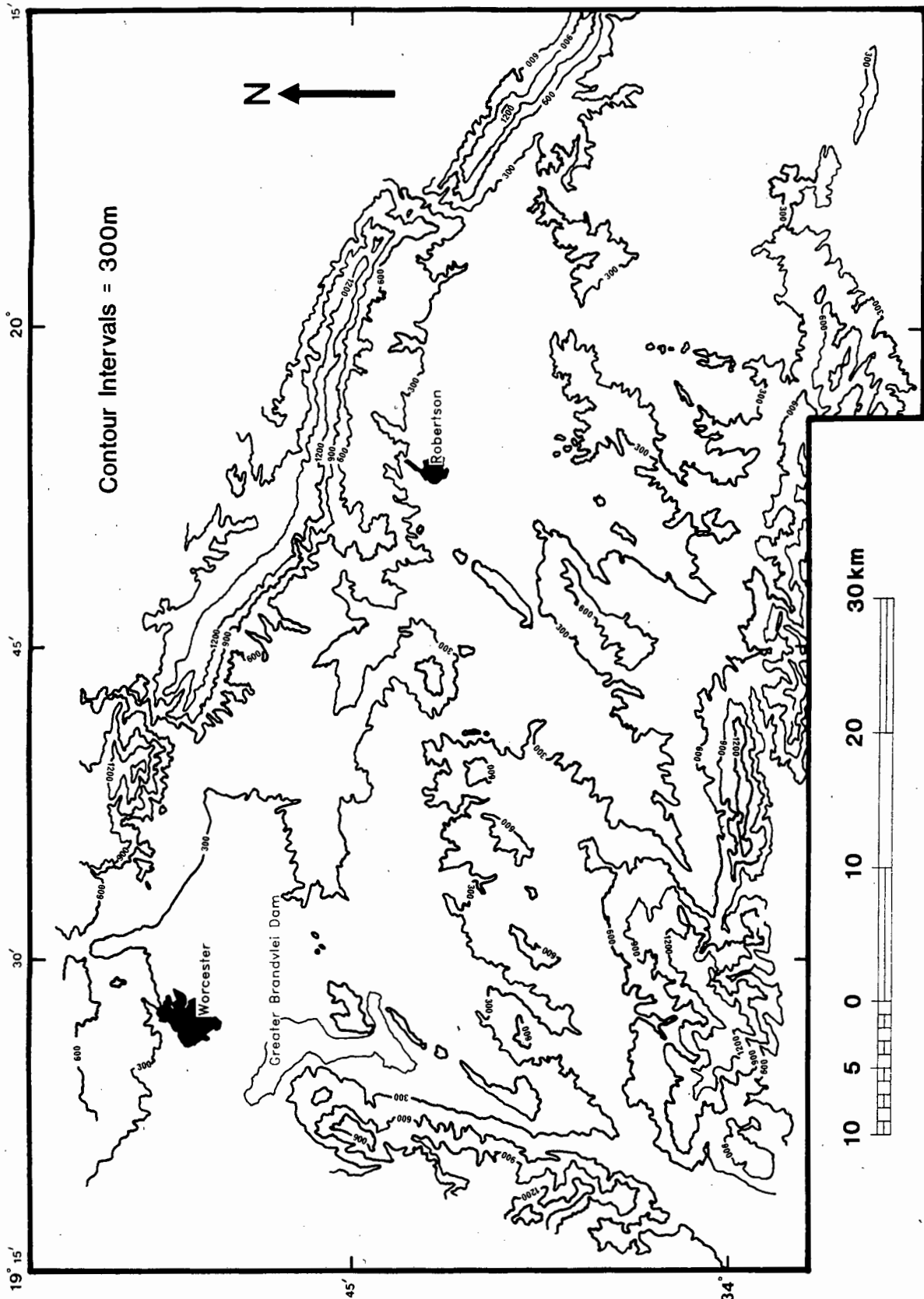


Fig. 4.3: Topography of the Middle Breede River Valley

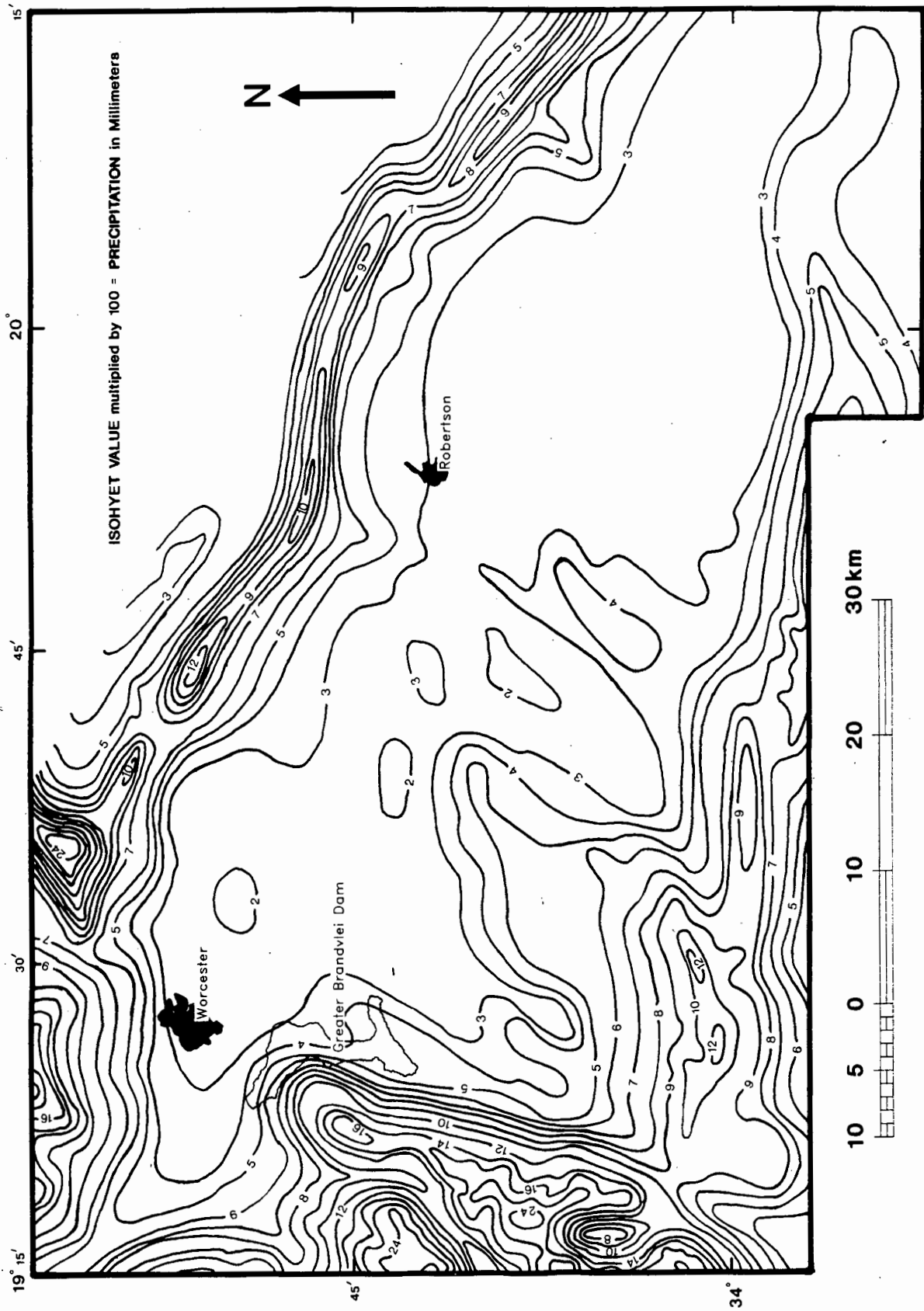


Fig. 4.4: Precipitation isohyets of the Middle Breede River Valley

- (ii) 1:250 000 - 3320 Ladismith (3rd ed.; 1985)
- (iii) 1:250 000 3420 Riversdale (4th ed.; 1985)

d) Precipitation

The map was obtained from the following precipitation maps:

- (i) 1:250 000 map - 3319 Worcester (1st ed.; 1966)
- (ii) 1:250 000 map - 3320 Ladismith (1st ed.; 1966)
- (iii) 1:250 000 map - 3420 Riversdale (1st ed.; 1966)

4.2.2.2 Division into "natural area units"

A transparency of the 1:250 000 soil map (Fig.4.2) was drawn and overlaid on the 1:250 000 geology map (Fig.4.1). Areas of different geologies were then drawn onto this overlying transparency. Soil and geology distributions virtually matched, but the boundaries of some of these regions overlapped to a small degree and it was necessary to simplify them on the transparency by drawing a single line through the overlapping areas. The areas were further divided into those below the 600mm precipitation isohyet (Karoo and Renosterveld) and those areas above this isohyet (Fynbos) (Campbell 1985).

4.2.2.3 Agricultural threat indices

The agricultural threat to each "natural area unit" was calculated using the following formula (This method was adapted from McDowell (1988) who assessed the agricultural threat to remnant islands of West Coast Renosterveld):

$$AT= SQI*PI*GI$$

where

AT = Agricultural Threat

SQI = Soil Quality Index for each area

PI = Precipitation Index for each site

GI = Slope Gradient Index for each site

The three indices were multiplied as there is no indication that one factor should be weighted above the others (McDowell 1988). For the purpose of this calculation all other parameters were assumed equal.

a) Soil Quality Index

By consulting experts in the field (Drs W. Bond, W. Stock & E. Witkowski pers. comm.), the sixteen different categories of soils occurring in the middle Breede River valley were fitted into the 11 working units used by McDowell (1988), see Table 4.1. He rated the agricultural potential of each soil unit on a scale of 1-100 for the south western Cape. The agricultural potential of each soil unit was used as the soil quality index.

b) Slope Gradient Index

Slope gradients were obtained for each of the "natural area units" by averaging the slope found (along lines perpendicular to the contour lines) at several points along the entire length of the area. As a decrease in ploughed lands occurs only at gradients greater than 20% (McDowell 1988), each area was categorized into low (0-20%), medium (>20%-40%) and high (>40%) slope gradient classes. The slope gradient index (GI) for each class was calculated by taking the inverse of the median of the

its areas at a distance from the rivers (Fig 4.6). These areas, as expected, have a higher percentage of remaining vegetation (Table 4.4).

On average the amount of remaining vegetation for all of the above classes (Classes 2-5) is approximately 50%. However, the variations from the expected in these classes appear to be related to the distance of these areas from a river, i.e. a water source for irrigation. Other variations can be explained by urbanization and mining to a limited extent.

Areas with a threat index of less than 500, as expected, are not cultivated to any extent (Table 4.4). The majority of these areas correspond to hilly regions within the study area and to the mountains in the North, West and South.

4.3.6 Spearman rank correlation

Before the statistical analysis was performed, areas not used for agriculture were removed from the data set, i.e. all the large areas owned by the Worcester and Robertson Municipalities, Department of Water Affairs and Department of Prisons. The Spearman rank correlation shows that the agricultural threat indices are significantly correlated with the past clearance of the vegetation ($r_s(2)=0.6025$; $P<0.001$). Therefore, these agricultural threat indices can predict the likelihood of agricultural expansion in a certain area.

Table 4.1: Soil quality rating

Average Agricultural Potential Rating (1-100) ¹	% soil unit under natural vegetation	Description of Soil Unit	Soil Type No.
93	50.00	Red & yellow well drained apedal soil e.g. Hutton, Clovelly, Avalon, & Bainsvlei	1-10
84	37.78	Dry to moderately drained non-saline alluvial soil e.g. Oakleaf, Dundee	24
65	57.22	Deeper residual soil e.g. Glenrosa, Swartland (not red B), Sterkspruit (not red B)	17
53	40.92	Red duplex soil e.g. Shortlands, Swartland, Strekspruit, Vaisrivier	11-15
39	30.42	Relative wet duplex soil e.g. Kroonstad, Escourt	18-21
38	23.47	Wet non-saline alluvial soil e.g. Westleigh, Avalon, Oakleaf	25
35	63.32	Shallow residual soil e.g. Mispah, Glenrosa, Swartland	16
34	59.28	Sandy acid soil e.g. Fernwood, Constantia, Lamotte	27
21	24.98	Saline alluvial soil	26
20	75.98	Talus material with undifferentiated rock	29
2	93.55	Rocky outcrops	30

¹ McDowell 1988

slope gradient range e.g. Class 1 (0-20%) : $GI = (0+20)/2)^{-1} = 0.1$. It was decided to invert the median because of the apparent inverse relationship between slope and the area of virgin land ploughed.

c) Precipitation Index

A transparency of the 1:250 000 precipitation map was laid over the map of the "natural area units" and the following method was used to calculate the precipitation index (PI) in each unit.

A line was drawn through each unit perpendicular to the surrounding isohyets to give two points on the unit's boundary. The precipitation at each of these points was estimated from the surrounding isohyets (using a weighted average). The median of the precipitation at these two points was then used as the precipitation index (PI).

4.2.2.4 Remaining natural vegetation in each "natural area unit"

A map was drawn up showing the extent of the remaining natural vegetation in each "natural area unit" (a map of the remaining natural vegetation was obtained from Fig. 3.2, Chapter 3). The extent of each "natural area unit" and the extent of that unit under remaining natural vegetation was calculated using a Summagraphics Digitizer connected to a A0 Table. This enabled the percentage remaining natural vegetation to be worked out for each unit.

4.2.2.5 Statistical analysis

The relationship between the agricultural threat indices and the past clearance of the vegetation was then statistically tested using a Spearman rank correlation, as this method is non-parametric and therefore does not assume that the data has a normal distribution.

4.3 RESULTS AND DISCUSSION

4.3.1 "Natural area units" and the percentage remaining vegetation in each unit

Dividing the Robertson Karoo resulted in 275 areas (Fig. 4.5) depicting 227 different soil, geology and rainfall combinations. In Table 4.2 the percentage of remaining natural vegetation in each area is shown.

4.3.2 Soil type

The percentage of each soil unit under remaining natural vegetation (Table 4.1) shows that soil type no's 1-10, 24, 11-15 to be the extensively cultivated. All these above soil types are regarded as having a high agricultural potential (potential >52), and, as expected, appear to be selectively cultivated.

However, soil types 25 (wet non-saline alluvial soil) and 26 (saline alluvial soil), which have a relatively low agricultural potential, are also extensively cultivated (Table 4.1). Less than 39% of the three alluvial soil types (24, 25, 26) are covered by natural vegetation. This is a lower than for the majority of the soil types, indicating that these areas are

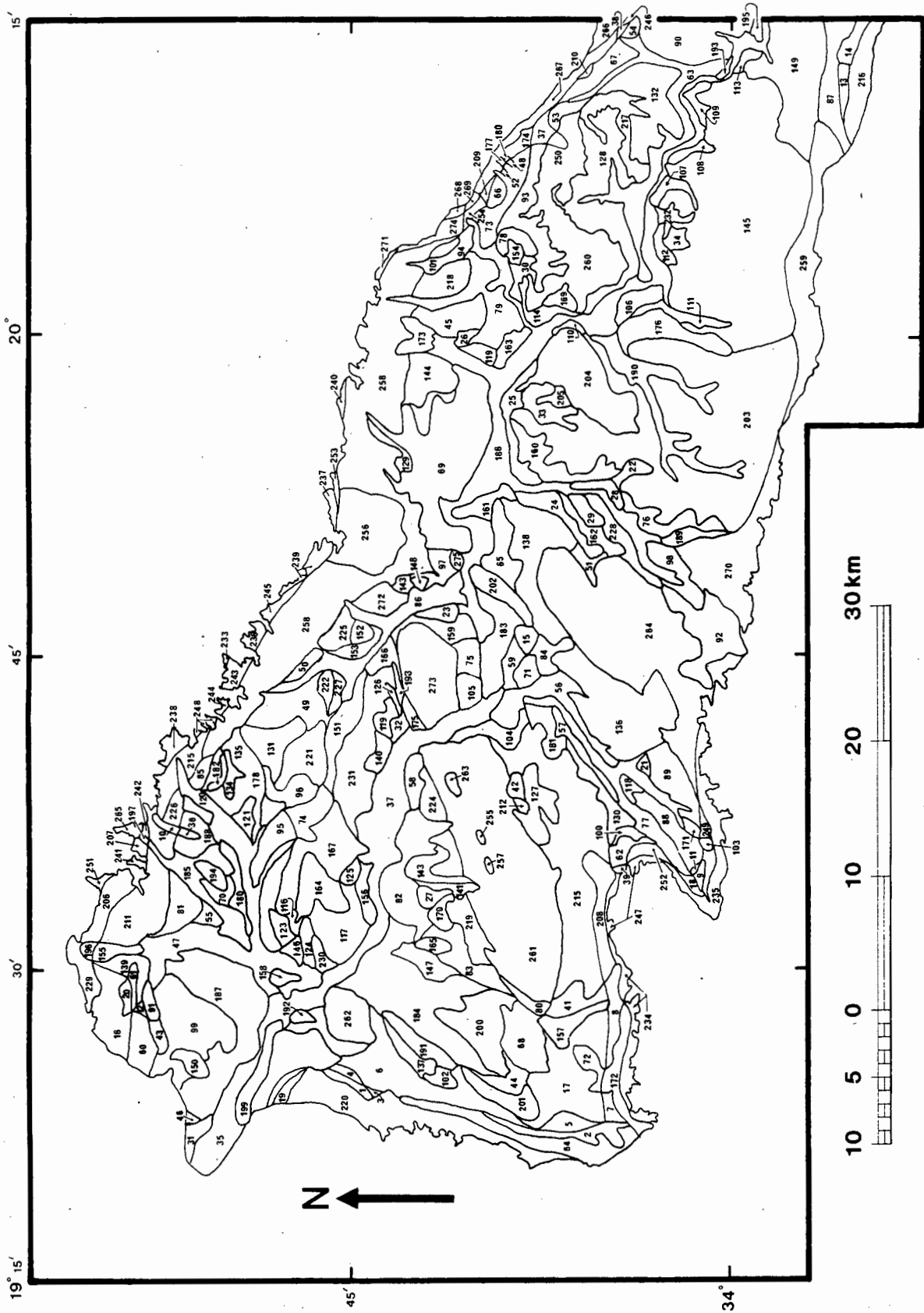


Fig. 4.5: The 275 resultant areas of different soil, geology and precipitation (key = see Table 5.3)

Table 4.2: Agricultural threat indices ranked from highest to lowest

Area no.*	area (m ²)	area under natural veld	% area under natural veld	Geology	Soil	SP*	Rainfall	Gradient	AGRICULTURAL THREAT INDEX
1	2107500	1259062.5	59.74	Bokkeveld group	3	93	725	0.1	6742.50
2	7446562.5	0	0.00	Bokkeveld group	24	84	700	0.1	5880.00
3	371250	0	0.00	Bokkeveld group	24	84	650	0.1	5460.00
4	1493750	0	0.00	Bokkeveld group	3	93	525	0.1	4882.50
5	3274687.5	0	0.00	Bokkeveld group	24	84	525	0.1	4410.00
6	26605312.5	8255187	31.03	Bokkeveld group	24	84	475	0.1	3990.00
7	3070937.5	0	0.00	Bokkeveld group	12	53	625	0.1	3312.50
8	6160937.5	3670312.5	59.57	Bokkeveld group	12	53	625	0.1	3312.50
9	667500	280312.5	41.99	Bokkeveld group	12	53	625	0.1	3312.50
10	1046660	372812.5	35.62	Malmesbury formation	24	84	375	0.1	3150.00
11	468750	0	0.00	Bokkeveld group	12	53	575	0.1	3047.50
12	360625	360625	100.00	Malmesbury formation	11	53	500	0.1	2650.00
13	2760625	331275	12.00	Alluvium	17	65	400	0.1	2600.00
14	4017187.5	0	0.00	Bokkeveld group	17	65	400	0.1	2600.00
15	2272500	1324375	58.28	Bokkeveld group	3	93	275	0.1	2557.50
16	11379687.5	9364562.5	82.29	Malmesbury formation	16	35	725	0.1	2537.50
17	28741875	9451562.5	32.88	Bokkeveld group	12	53	475	0.1	2517.50
18	1031250	1031250	100.00	Alluvium	25	38	650	0.1	2470.00
19	1875000	1055937.5	56.32	Bokkeveld group	27	34	725	0.1	2465.00
20	1447812.5	1447812.5	100.00	Biotite eucrite	16	35	675	0.1	2362.50
21	964687.5	0	0.00	Bokkeveld group	5	93	250	0.1	2325.00
22	1797187.5	1491937.5	83.02	Bokkeveld group	5	93	250	0.1	2325.00
23	2553437.5	1274687.5	49.92	Alluvium	6	93	250	0.1	2325.00
24	6110625	2788125	45.63	Alluvium	5+6	93	250	0.1	2325.00
25	9445625	4050312.5	42.88	Alluvium	6	93	250	0.1	2325.00
26	1397187.5	0	0.00	Alluvium	6	93	250	0.1	2325.00
27	3284375	270312.5	8.23	Alluvium	5	93	250	0.1	2325.00
28	1742187.5	793125	45.52	Alluvium	5	93	250	0.1	2325.00
29	4344375	2741562.5	63.11	Alluvium	5	93	250	0.1	2325.00
30	3263750	1495937.5	45.83	Alluvium	5	93	250	0.1	2325.00
31	3261562.5	1596250	48.94	Alluvium	3	93	250	0.1	2325.00
32	2657187.5	270312.5	10.17	Alluvium	10	93	250	0.1	2325.00
33	8783437.5	8783437.5	100.00	Bokkeveld group	6	93	250	0.1	2325.00
34	1953125	1552812.5	79.50	Bokkeveld group	9	93	250	0.1	2325.00
35	67425625	38430937.5	57.00	Alluvium	24	84	275	0.1	2310.00
36	894277.5	501531.5	56.08	Ecce group	24	84	275	0.1	2310.00
37	2977300	199000	6.68	Witteberg group	16	35	650	0.1	2275.00
38	348750	139500	40	Malmesbury formation	16	35	650	0.1	2275.00
39	661562.5	661562.5	100.00	Table mountain group	16	35	625	0.1	2187.50
40	1585937.5	668125	42.13	Bokkeveld group	16	35	625	0.1	2187.50
41	5567812.5	4768125	85.64	Bokkeveld group	12	53	400	0.1	2120.00
42	2134687.5	1117187.5	52.33	Bokkeveld group	12	53	400	0.1	2120.00
43	1701562.5	286875	16.86	Enon conglomerate	11	53	400	0.1	2120.00
44	5232812.5	2260312.5	43.19	Witteberg group	12	53	400	0.1	2120.00
45	11123906.25	990000	8.90	Enon conglomerate	13	53	400	0.1	2120.00
46	314375	314375	100	Alluvium	24	84	250	0.1	2100.00
47	41070625	9760625	23.77	Alluvium	24	84	250	0.1	2100.00

48	277812.5	0	0.00	Malmesbury formation	16	35	575	0.1	2012.50
49	20318750	13240312.5	65.16	Ecce group	12+13	53	375	0.1	1987.50
50	3038125	1487812.5	48.97	Ecce group	12	53	375	0.1	1987.50
51	1350000	1300000	96.30	Alluvium	17	65	300	0.1	1950.00
52	207500	0	0.00	Alluvium	16	35	550	0.1	1925.00
53	3031875	1495625	49.33	Witteberg group	16	35	550	0.1	1925.00
54	1003750	600000	59.78	Malmesbury formation	16	35	550	0.1	1925.00
55	2206562.5	0	0.00	Alluvium	3	93	200	0.1	1860.00
56	13171875	2520312.5	19.13	Alluvium	5	93	200	0.1	1860.00
57	5330312.5	2369375	44.45	Alluvium	5	93	200	0.1	1860.00
58	3839687.5	1021250	26.60	Dwyka group	5	93	200	0.1	1860.00
59	3723750	795000	21.35	Alluvium	3	93	200	0.1	1860.00
60	6145625	6137812.5	100.00	Malmesbury formation	16	35	525	0.1	1837.50
61	1801250	1801250	100.00	Biotite eucrite	16	35	525	0.1	1837.50
62	4155000	4155000	100.00	Table mountain group	16	35	525	0.1	1837.50
63	35939375	5151033	14.33	Alluvium	15	53	343.75	0.1	1821.88
64	15960000	3978437.5	24.93	Bokkeveld group	17	65	850	0.0328	1812.20
65	8396250	7438875	88.57	Alluvium	17	65	275	0.1	1787.50
66	1890625	0	0.00	Witteberg group	16	35	500	0.1	1750.00
67	10811562.5	1626639.75	15.05	Witteberg group	16	35	500	0.1	1750.00
68	19538125	8594375	43.99	Dwyka group	12	53	325	0.1	1722.50
69	55257812.5	14578687.5	26.38	Alluvium	12+13	53	325	0.1	1722.50
70	2666562.5	450937.5	16.91	Alluvium	24	84	200	0.1	1680.00
71	2613125	0	0.00	Alluvium	24	84	200	0.1	1680.00
72	5477500	4105312.5	74.95	Bokkeveld group	16	35	475	0.1	1662.50
73	8525000	1105937.5	12.97	Alluvium	16	35	475	0.1	1662.50
74	4464375	4464375	100	Ecce group	17	65	250	0.1	1625.00
75	4131875	3321562.5	80.39	Bokkeveld group	17	65	250	0.1	1625.00
76	7866250	6475000	82.31	Bokkeveld group	17	65	250	0.1	1625.00
77	20906875	4905937.5	23.47	Alluvium	25	38	425	0.1	1615.00
78	3189062	0	0.00	Alluvium	15	53	300	0.1	1590.00
79	16806562.5	504687.5	3.60	Alluvium	15	53	300	0.1	1590.00
80	3288750	2013125	61.21	Witteberg group	12	53	300	0.1	1590.00
81	7166250	0	0.00	Ecce group	12	53	300	0.1	1590.00
82	19891250	13138750	66.05	Alluvium	12	53	300	0.1	1590.00
83	8603125	4537187.5	52.74	Dwyka group	12	53	300	0.1	1590.00
84	3154687.5	2441250	77.38	Bokkeveld group	12	53	300	0.1	1590.00
85	1629062.5	237812.5	14.60	Malmesbury formation	12	53	300	0.1	1590.00
86	19185937.5	9537750	49.71	Alluvium	12+13	53	300	0.1	1590.00
87	16847187.5	1684718.75	10.00	Alluvium	18/20+25	39	400	0.1	1548.00
88	9642812.5	1999062.5	20.73	Bokkeveld group	16	35	425	0.1	1487.50
89	17233375	8322037.5	48.29	Bokkeveld group	16	35	425	0.1	1487.50
90	12038125	2755937.5	22.89	Bokkeveld group	16	35	425	0.1	1487.50
91	2038437.5	2038437.5	100.00	Enon conglomerate	16	35	425	0.1	1487.50
92	19592187.5	12964250	66.17	Table mountain group	16	35	425	0.1	1487.50
93	17583125	6319062.5	35.94	Witteberg group	16	35	425	0.1	1487.50
94	5878125	1273750	21.67	Alluvium	16	35	425	0.1	1487.50
95	7619375	5572187.5	73.13	Enon conglomerate	17	65	225	0.1	1462.50
96	10043750	9725312.5	96.83	Ecce group	12	53	275	0.1	1457.50
97	4650000	4103125	88.24	Bokkeveld group	12	53	275	0.1	1457.50
98	9071250	1586250	17.49	Alluvium	12	53	275	0.1	1457.50
99	24711250	4779062.5	19.34	Alluvium	11	53	268.75	0.1	1424.38
100	1518125	1518125	100.00	Bokkeveld group	16	35	400	0.1	1400.00
101	403120.5	200000	49.61	Enon conglomerate	16	35	400	0.1	1400.00
102	3715937.5	2536250	68.25	Bokkeveld group	20	39	350	0.1	1365.00
103	891250	0	0.00	Bokkeveld group	17	65	625	0.0328	1332.50

104	6424062.5	3897187.5	60.67	Bokkeveld group	12	53	250	0.1	1325.00
105	3305937.5	2975000	89.99	Bokkeveld group	12	53	250	0.1	1325.00
106	5090625	0	0.00	Alluvium	15	53	250	0.1	1325.00
107	2813437.5	652187.5	23.18	Alluvium	15	53	250	0.1	1325.00
108	1967187.5	204375	10.39	Alluvium	15	53	250	0.1	1325.00
109	1948437.5	109375	5.61	Alluvium	15	53	250	0.1	1325.00
110	1251250	514000	41.08	Alluvium	15	53	250	0.1	1325.00
111	5344062.5	0	0.00	Bokkeveld group	15	53	250	0.1	1325.00
112	2422812.5	109375	4.51	Bokkeveld group	15	53	250	0.1	1325.00
113	2301250	419375	18.22	Bokkeveld group	15	53	250	0.1	1325.00
114	2824062.5	475937.5	16.85	Alluvium	15	53	250	0.1	1325.00
115	1187812.5	1187812.5	100.00	Dwyka group	12	53	250	0.1	1325.00
116	15309062.5	14379062.5	93.93	Dwyka group	12	53	250	0.1	1325.00
117	3269375	3269375	100.00	Dwyka group	12	53	250	0.1	1325.00
118	1932500	1289687.5	66.74	Alluvium	12	53	250	0.1	1325.00
119	2609062.5	0	0.00	Alluvium	12	53	250	0.1	1325.00
120	1895625	0	0.00	Alluvium	12	53	250	0.1	1325.00
121	2821875	0	0.00	Enon conglomerate	13	53	250	0.1	1325.00
122	7460625	6085937.5	81.57	Alluvium	12	53	250	0.1	1325.00
123	3090937.5	2642812.5	85.50	Enon conglomerate	12	53	250	0.1	1325.00
124	3205625	1462187.5	45.61	Witteberg group	12	53	250	0.1	1325.00
125	2162187.5	1972812.5	91.24	Ecce group	12	53	250	0.1	1325.00
126	1040312.5	1040312.5	100.00	Witteberg group	12	53	250	0.1	1325.00
127	9681562.5	8975937.5	92.71	Bokkeveld group	16	35	375	0.1	1312.50
128	31514375	22444375	71.22	Bokkeveld group	16	35	375	0.1	1312.50
129	2878437.5	1425000	49.51	Malmesbury formation	16	35	375	0.1	1312.50
130	6483125	5572500	85.95	Alluvium	16	35	350	0.1	1225.00
131	17624687.5	16824687.5	95.46	Ecce group	16	35	350	0.1	1225.00
132	26802812.5	8057500	30.06	Bokkeveld group	16	35	350	0.1	1225.00
133	5521875	2694375	48.79	Bokkeveld group	27	34	350	0.1	1190.00
134	1228750	851250	69.28	Enon conglomerate	20	39	300	0.1	1170.00
135	868437.5	502500	57.86	Ecce group	20	39	300	0.1	1170.00
136	40502812.5	38207187.5	94.33	Bokkeveld group	16	35	325	0.1	1137.50
137	3380156.25	3380156.25	100.00	Bokkeveld group	27	34	325	0.1	1105.00
138	24361875	23566250	96.73	Bokkeveld group	16	35	312.5	0.1	1093.75
139	4568125	3514375	76.93	Malmesbury formation	16	35	950	0.0328	1090.60
140	3674687.5	2841250	77.32	Alluvium	12	53	200	0.1	1060.00
141	2426562.5	1850937.5	76.28	Alluvium	16	35	300	0.1	1050.00
142	1385625	671089.5	48.43	Alluvium	16	35	300	0.1	1050.00
143	5098437.5	4792531.25	94.00	Dwyka group	16	35	300	0.1	1050.00
144	9919687.5	2688125	27.10	Enon conglomerate	16	35	300	0.1	1050.00
145	129187500	69642500	53.91	Bokkeveld group	16	35	300	0.1	1050.00
146	1995937.5	0	0.00	Enon conglomerate	21	39	250	0.1	975.00
147	6438125	0	0.00	Dwyka group	20	39	250	0.1	975.00
148	850156.25	850156.25	100.00	Bokkeveld group	16	35	275	0.1	962.50
149	35939687.5	4824062.5	13.42	Bokkeveld group	16	35	275	0.1	962.50
150	3610625	2450937.5	67.88	Enon conglomerate	16	35	275	0.1	962.50
151	7282500	7282500	100	Ecce group	16	35	275	0.1	962.50
152	2200625	1994375	90.63	Dwyka group	16	35	275	0.1	962.50
153	3809687.5	3219375	84.50	Alluvium	16	35	275	0.1	962.50
154	1520312.5	0	0.00	Alluvium	16	35	275	0.1	962.50
155	8344062.5	0	0.00	Alluvium	29	20	475	0.1	950.00
156	3362500	610937	18.17	Alluvium	25	38	250	0.1	950.00
157	5323125	2024687.5	38.04	Bokkeveld group	26	21	425	0.1	892.50
158	1918750	0	0.00	Alluvium	16	35	250	0.1	875.00
159	7010937.5	6533125	93.18	Bokkeveld group	16	35	250	0.1	875.00

160	11918750	11918750	100.00	Bokkeveld group	16	35	250	0.1	875.00
161	4375000	1907187.5	43.59	Alluvium	16	35	250	0.1	875.00
162	4738750	3608437.5	76.15	Alluvium	16	35	250	0.1	875.00
163	3658750	0	0.00	Alluvium	16	35	250	0.1	875.00
164	11000937.5	11000937.5	100.00	Dwyka group	16	35	250	0.1	875.00
165	2496250	0	0.00	Dwyka group	16	35	250	0.1	875.00
166	3573906.25	3573906.25	100.00	Dwyka group	16	35	250	0.1	875.00
167	16070312.5	16070312.5	100.00	Ecce group	16	35	250	0.1	875.00
168	7400000	4048437.5	54.71	Enon conglomerate	16	35	250	0.1	875.00
169	2274062.5	2074062.5	91.21	Witteberg group	16	35	250	0.1	875.00
170	2584687.5	1134062.5	43.88	Dwyka group	27	34	250	0.1	850.00
171	1445687.5	578275	40.00	Bokkeveld group	29	20	425	0.1	850.00
172	8995000	8353750	92.87	Bokkeveld group	16	35	700	0.0328	803.60
173	4640625	1998750	43.07	Enon conglomerate	26	21	375	0.1	787.50
174	2106875	1189062.5	56.44	Alluvium	16	35	675	0.0328	774.90
175	3117812.5	2727500	87.48	Alluvium	3	93	250	0.0328	762.60
176	15022500	12800625	85.21	Bokkeveld group	10	93	250	0.0328	762.60
177	358750	0	0.00	Alluvium	16	35	650	0.0328	746.20
178	11248125	7470000	66.41	Enon conglomerate	26	21	350	0.1	735.00
179	4951875	1951250	39.40	Alluvium	21	39	187.5	0.1	731.25
180	140937.5	140937.5	100	Malmesbury formation	16	35	625	0.0328	717.50
181	5594375	4966250	88.77	Bokkeveld group	16	35	200	0.1	700.00
182	1250937.5	752500	60.15	Ecce group	26	21	325	0.1	682.50
183	12784062.5	7234375	56.59	Alluvium	27	34	200	0.1	680.00
184	45442187.5	6819375	15.01	Alluvium	26	21	287.5	0.1	603.75
185	18095937.5	2050625	11.33	Alluvium	26	21	287.5	0.1	603.75
186	86707812.5	11686875	13.48	Alluvium	26	21	268.75	0.1	564.38
187	40455312.5	37837187.5	93.53	Alluvium	29	20	275	0.1	550.00
188	5894375	5015312.5	85.09	Ecce group	29	20	275	0.1	550.00
189	2374062.5	1445937.5	60.91	Table mountain group	26	21	250	0.1	525.00
190	30350625	17036575	56.13	Bokkeveld group	26	21	250	0.1	525.00
191	7608756	7248437.5	95.26	Witteberg group	12	53	300	0.0328	521.52
192	1464687.5	1464687.5	100.00	Witteberg group	14	53	300	0.0328	521.52
193	618437.5	532187.5	86.05	Alluvium	29	20	250	0.1	500.00
194	2584687.5	1439062.5	55.68	Alluvium	29	20	250	0.1	500.00
195	955937.5	318125	33.28	Bokkeveld group	29	20	250	0.1	500.00
196	1810000	596718.75	32.97	Alluvium	29	20	725	0.0328	475.60
197	277812.5	91678.125	33	Alluvium	26	21	650	0.0328	447.72
198	1302812.5	1302812.5	100.00	Alluvium	12	53	250	0.0328	434.60
199	8641250	8641250	100.00	Witteberg group	16	35	350	0.0328	401.80
200	17276875	16307500	94.39	Witteberg group	16	35	350	0.0328	401.80
201	5231562.5	5231562.5	100.00	Witteberg group	16	35	450	0.0167	263.03
202	7127500	6285937.5	88.19	Table mountain group	29	20	300	0.0328	196.80
203	132267187.5	99490000	75.22	Bokkeveld group	30+16	18.5	287.5	0.0328	174.46
204	25606562.5	25606562.5	100.00	Witteberg group	30+16	18.5	250	0.0328	151.70
205	2093750	2093750	100.00	Bokkeveld group	30+16	18.5	250	0.0328	151.70
206	7999062.5	7313750	91.43	Malmesbury formation	30	2	700	0.1	140.00
207	1001250	1001250	100.00	Malmesbury formation	30	2	625	0.1	125.00
208	13653437.5	9555000	69.98	Bokkeveld group	30	2	625	0.1	125.00
209	804687.5	169562.5	21.07	Malmesbury formation	30	2	550	0.1	110.00
210	380000	380000	100.00	Malmesbury formation	30	2	550	0.1	110.00
211	16746250	11757812.5	70.21	Malmesbury formation	30	2	450	0.1	90.00
212	891250	891250	100.00	Bokkeveld group	30	2	450	0.1	90.00
213	8096562.5	7630937.5	94.25	Table mountain group	30	2	450	0.1	90.00
214	3006562.5	2716812.5	90.00	Malmesbury formation	30	2	425	0.1	85.00
215	62698125	62698125	100.00	Bokkeveld group	30	2	425	0.1	85.00

216	15319687.5	15319687.5	100.00	Table mountain group	30	2	400	0.1	80.00
217	11053125	7704375	69.70	Bokkeveld group	30	2	375	0.1	75.00
218	8057187.5	4982187.5	61.84	Enon conglomerate	30	2	375	0.1	75.00
219	8740000	6740000	100.00	Dwyka group	30	2	350	0.1	70.00
220	35205937.5	35205937.5	100.00	Table mountain group	30	2	1000	0.0328	65.60
221	15795312.5	15795312.5	100.00	Eccla group	30	2	300	0.1	60.00
222	2670000	2670000	100.00	Eccla group	30	2	300	0.1	60.00
223	5076250	5076250	100.00	Dwyka group	30	2	300	0.1	60.00
224	5906250	5906250	100.00	Dwyka group	30	2	300	0.1	60.00
225	4640000	3066250	66.08	Dwyka group	30	2	300	0.1	60.00
226	2754687.5	2185000	79.32	Malmesbury formation	30	2	300	0.1	60.00
227	2200000	2200000	100	Alluvium	30	2	275	0.1	55.00
228	7515625	6940620.5	92.35	Alluvium	30	2	275	0.1	55.00
229	4917812.5	3664687.5	74.52	Table mountain group	30	2	762.5	0.0328	50.92
230	2990937.5	2990937.5	100.00	Witteberg group	30	2	250	0.1	50.00
231	23243437.5	23243437.5	100.00	Dwyka group	30	2	250	0.1	50.00
232	2735312.5	2304062.5	84.23	Bokkeveld group	30	2	250	0.1	50.00
233	264687.5	264687.5	100.00	Table mountain group	30	2	750	0.0328	49.20
234	8387812.5	8387812.5	100.00	Table mountain group	30	2	725	0.0328	47.56
235	13461562.5	13461562.5	100.00	Table mountain group	30	2	700	0.0328	45.92
236	1755781.25	1755781.25	100.00	Malmesbury formation	30	2	700	0.0328	45.92
237	1537812.5	1537812.5	100.00	Table mountain group	30	2	675	0.0328	44.28
238	3742187.5	3742187.5	100.00	Table mountain group	30	2	650	0.0328	42.64
239	835781.25	835781.25	100.00	Table mountain group	30	2	650	0.0328	42.64
240	753750	753750	100.00	Table mountain group	30	2	650	0.0328	42.64
241	423437.5	423437.5	100.00	Malmesbury formation	30	2	650	0.0328	42.64
242	353125	353125	100.00	Malmesbury formation	30	2	650	0.0328	42.64
243	3404531.25	3404531.25	100.00	Malmesbury formation	30	2	650	0.0328	42.64
244	504687.5	504687.5	100.00	Malmesbury formation	30	2	625	0.0328	41.00
245	1840875	1840875	100.00	Malmesbury formation	30	2	625	0.0328	41.00
246	187812.5	187812.5	100.00	Malmesbury formation	30	2	625	0.0328	41.00
247	3713750	3067812.5	82.61	Table mountain group	30	2	625	0.0328	41.00
248	1348125	1348125	100.00	Table mountain group	30	2	625	0.0328	41.00
249	1405000	1200000	85.41	Bokkeveld group	30	2	625	0.0328	41.00
250	1186875	1186875	100.00	Witteberg group	30	2	625	0.0328	41.00
251	666250	666250	100.00	Table mountain group	30	2	1100	0.0167	36.74
252	2522812.5	2522812.5	100.00	Table mountain group	30	2	550	0.0328	36.08
253	715000	715000	100.00	Table mountain group	30	2	550	0.0328	36.08
254	1797500	1215312.5	67.61	Alluvium	30	2	550	0.0328	36.08
255	490937.5	490937.5	100.00	Dwyka group	30	2	475	0.0328	31.16
256	28504687.5	24828437.5	92.92	Granite	30	2	475	0.0328	31.16
257	567187.5	567187.5	100.00	Dwyka group	30	2	450	0.0328	29.52
258	118860000	100043125	85.61	Malmesbury formation	30	2	450	0.0328	29.52
259	29500625	27605000	93.57	Table mountain group	30	2	450	0.0328	29.52
260	43168437.5	42168437.5	97.68	Witteberg group	30	2	450	0.0328	29.52
261	104142656.25	101987656.25	97.93	Witteberg group	30	2	408	0.0328	26.76
262	11779687.5	11511250	97.72	Witteberg group	30	2	400	0.0328	26.24
263	1127343.75	1127343.75	100.00	Dwyka group	30	2	400	0.0328	26.24
264	87535781.25	86456093.75	98.77	Table mountain group	30	2	400	0.0328	26.24
265	1322187.5	1322187.5	100.00	Table mountain group	30	2	750	0.0167	25.05
266	3770000	3770000	100.00	Table mountain group	30	2	725	0.0167	24.22
267	9135000	9135000	100.00	Malmesbury formation	30	2	700	0.0167	23.38
268	1453906.25	1453906.25	100.00	Tafelberg group	30	2	650	0.0167	21.71
269	916250	916250	100.00	Alluvium	30	2	650	0.0167	21.71
270	29203750	24683750	84.52	Table mountain group	30	2	325	0.0328	21.32
271	190000	190000	100.00	Table mountain group	30	2	625	0.0167	20.88

272	6130312.5	5752812.5	93.84	Witteberg group	30	2	300	0.0328	19.68
273	27246250	27246250	100.00	Witteberg group	30	2	300	0.0328	19.68
274	4500937.5	4500937.5	100.00	Table mountain group	30	2	525	0.0167	17.54
275	931250	810000	86.98	Table mountain group	30	2	250	0.0167	8.35
#	-	9467500	0	0.00	Brandvlei Dam		450	0.1	0.00
#	-	3697187.5	0	0.00	Brandvlei Dam		625	0.1	0.00

* see Fig 4.1

^ Soil type no.'s, see Table 4.1

~ Soil quality rating, see Table 4.1

Brandvlei Dam was excluded due to lack of information

selectively cultivated. Soil types 18-21 are also extensively cultivated. However, the reason for this is that these soils occur close to rivers and are therefore also selectively farmed. It can be concluded, that in the Robertson Karoo where agricultural expansion is limited by the available water, those soil types (e.g. 25, 26, 18-21), although they are rated as having a lower agricultural potential, are favoured for cultivation as they have easy access to water for irrigation (see chapter 3).

4.3.3 Slope gradient

Slope gradient analysis (Table 4.3) shows that around two-thirds of the study area has a gradient of less than or equal to 20%. Almost one third of the area has a gradient of >20% - 40%, whereas only 1% of the area has >40% gradient. As 47% of the areas with a gradient $\leq 20\%$ are cultivated, it is evident that these areas are more readily ploughed than the steeper slopes

Table 4.3: Proportion of study area in each gradient interval and percentage remaining natural vegetation.

Gradient Interval	%study area in each interval	%gradient interval natural veld
$\leq 20\%$	68.56	52.70
21-40%	30.41	89.47
>40%	1.03	99.57

(Table 4.3). Above this gradient there is a rapid decrease in cultivated lands as a result of the physical constraints in ploughing on steep slopes and the fact that soils of these slopes are shallow and more prone to erosion (McDowell 1988). Recent legislation (Anon. 1984) supports the idea that the 20% gradient is an important limit, as above this gradient permits for the cultivation of virgin land are unlikely to be granted.

4.3.4 Precipitation

Precipitation analysis shows that the majority of the area has a mean annual precipitation of around 250 mm (Table 4.2). For agricultural purposes it is generally necessary, therefore, to irrigate most of the cultivated lands in the area (see Chapter 3). Hence, distance from a river or water source is an important limitation in the spread of agriculture (Chapter 3).

4.3.5 Agricultural threat indices

The agricultural threat indices for the entire study area are listed in descending order (Table 4.2). For practical purposes, the agricultural threat indices are divided into 7 classes (Table 4.4) and illustrated in Fig 4.6. The remaining natural vegetation (Fig. 4.7) is presented as an overlay to Fig. 4.6. to show the past clearance in relation to the agricultural threat classes. The total area and percentage remaining vegetation in each class is shown in Table 4.2 along with the geology, soil type, slope gradient and precipitation of each area.

Table 4.4: Percentage of each agricultural threat class under remaining natural vegetation

Class	Agricultural potential class interval	%study area in each group	%class under natural vegetation
1	>3000	1.93	26.25
2	2000-2999	9.03	45.22
3	1500-1999	13.67	36.76
4	1000-1499	20.32	58.85
5	500-999	17.34	48.15
6	50-499	17.33	87.76
7	0-49	20.39	94.34

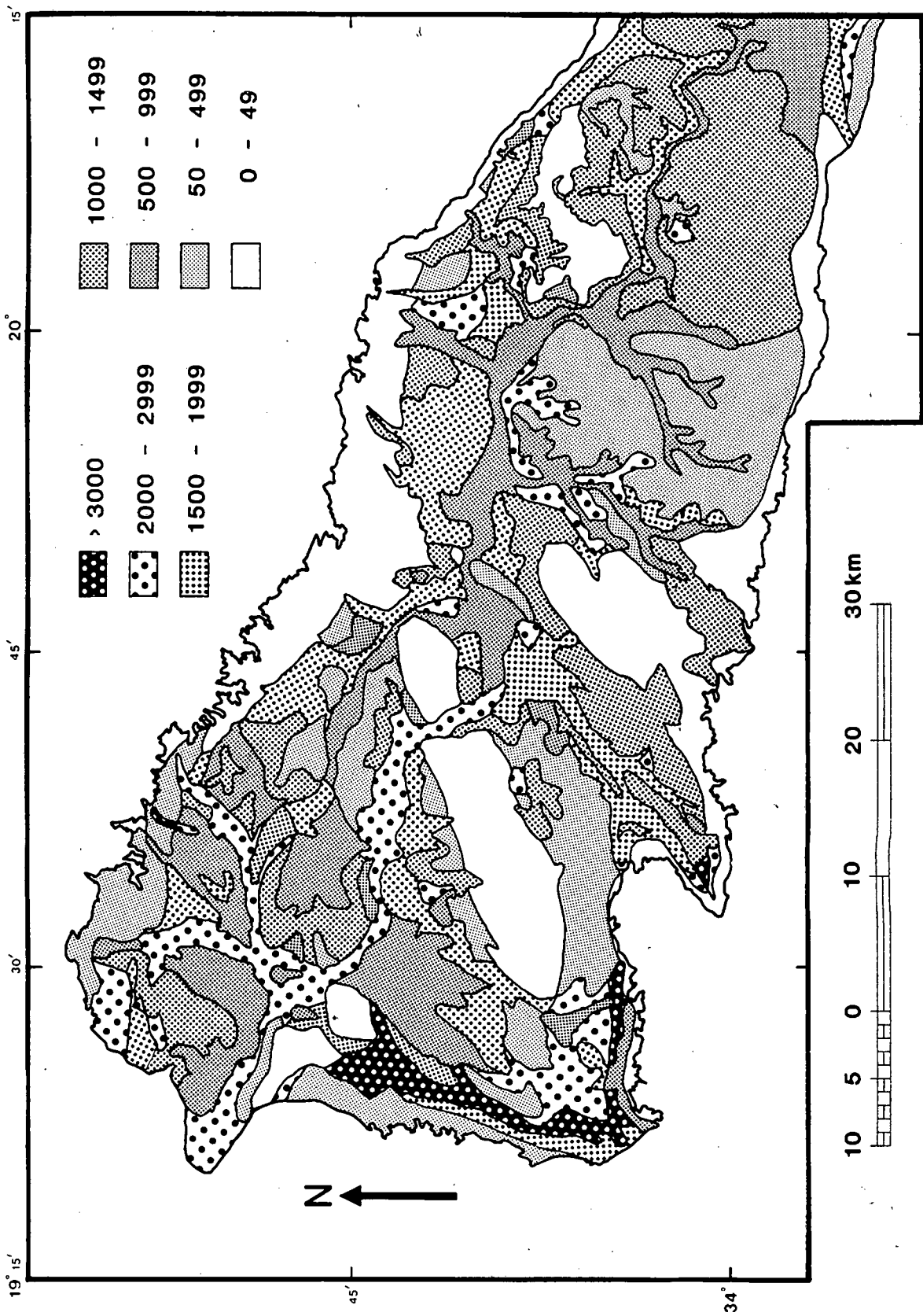


Fig. 4.6: Seven classes of agricultural threat indices

Table 4.4 shows that the threat indices of the 7 classes do relate broadly to the past clearance of the natural vegetation. Theoretically, the higher the agricultural threat index of an area, the lower the percentage remaining vegetation in that area.

It is apparent from Table 4.4 and Fig 4.6 that there is only a small proportion of the study area (1.93%) with high agricultural potentials (3000-7000). This is a result of there being few areas of fertile soils (soil potential >52) in combination with high rainfall (>400 mm.p.a.). Fig 4.6 shows that most of these areas occur in the west of the study area. As expected, a large amount of the natural vegetation other than that flooded by Kwaggaskloof Dam, has been cleared in this western sector. The only land not extensively cultivated is that owned by Brandvlei Prisons. This is because the Department of Prisons is not managed as a profit making agricultural enterprise.

The threat indices of the majority (48.05%) of the study area are between 500-3000. Many of the areas in this class have a river flowing through them, e.g. The Breede River in the western part of the valley as well as the Hex and Nuy Rivers flow through areas with indices between 2000-2999. In the eastern part of the valley, the Breede River flows through the areas with indices between 500-999. These areas close to the Breede River have a lower percentage remaining natural vegetation (47.83, Table 4.4). Only Class 4 (indices 1000-1499) has most of

4.4 CONCLUSIONS

The agricultural threat indices predict the likelihood of agricultural expansion in a particular area. It is clear that the agricultural threat is highest in areas in close proximity to rivers.

McDowell (1988) mentions the fact that these threat indices do not necessarily have any longer-term significance, i.e. they represent contemporary threat according to prevailing economic and technological constraints. The advancement of technology; e.g. breeding of resistant strains of crops and improved irrigation or fertilizing techniques may introduce a set of different parameters that may play an important role in the agricultural expansion. There is, accordingly, no absolute prediction for the agricultural potential of a certain area, as other factors can come into play such as the human influence which can ultimately override all other parameters.

These threat indices do, however, correlate significantly with past clearance of the natural vegetation, and so the resultant map (Fig. 4.6) is of great value in drawing up a conservation plan of action for the Robertson Karoo. More immediately, the map is used in the following chapter to predict the agricultural threat to areas of ecological interest and value.

**CHAPTER 5: THE IDENTIFICATION OF HIGH
PRIORITY CONSERVATION AREAS AND THE
IMPLICATIONS FOR THEIR MANAGEMENT**

5.1 INTRODUCTION

This chapter begins with a presentation of the current conservation status of the natural vegetation of the Robertson Karoo. This is followed by a discussion on how areas of high conservation value can be defined, together with criteria used for their assessment. Finally, recommendations on the management of these high priority conservation areas are discussed.

5.1.1 Conservation status

At present 2.39% of the Robertson Karoo (3.62% of the remaining vegetation) is "conserved" (Table 5.1). There is one provincial, one local and five private Nature Reserves, one National Botanic Garden and one Veld Reserve owned by the Department of Agriculture (Fig. 5.1). Three State Forest Reserves also border on the study area.

The private nature reserves are not regarded by the Cape Department of Nature and Environmental Conservation (CDNEC) as having high conservation status, as these are poorly monitored following their original assessment by the Department (CDNEC pers. comm.). Some view these reserves as only a short - term conservation option (Lloyd 1987). A questionnaire which was sent to each of the private nature reserve owners revealed that the current owners, although interested in conserving and managing the flora and fauna, had ill-defined management goals. Various

Table 5.1 : Conserved areas in the Robertson Karoo

Reserve Name	Total area (km ²) (***)	Area of natural veld (km ²)	Vegetation type ¹	Ownership
Vrolijkheid Provincial Nature Reserve	18.27 (18.27)	17.00	Karoo	CDNEC
Dassieshoek Municipality Nature Reserve	8.62 (5.17)	1.17	Renosterveld- Fynbos	Local Authority
Karoo Botanic Gardens	1.54 (1.54)	1.29	Karoo	National Botanic Gardens
Jonaskop Private NR	18.71 (2.10)	2.10	Fynbos	Private
Patryskloof Private NR	16.31 (2.61)	2.24	Fynbos	Private
Doringkloof Private NR	5.32 (3.99)	3.67	Fynbos	Private
Quaggaskloof Private NR	5.82 (5.82)	5.82	Renosterveld	Private
Goedemoed Private NR	19.5 (19.5)	19.50	Karoo	Private
Worcester Veld Reserve	1.27	0.68	Karoo	Dept. of Agriculture
STATE FORESTS				
Riversonderend	- (1.01)	1.01	Fynbos	
Twist Niet	- (0.1)	0.1	Fynbos	
Marloth	- (1.06)	1.06	Fynbos	
Mountain Catchment Area	- (101.9)	101.9	Fynbos	

*** Area of the reserve that falls within the study region

1 = Jarman 1986, CDNEC pers. comm.

CDNEC = Cape Department of Nature and Environmental Conservation

NR = Nature Reserve

: Summary of conserved areas

Conserved areas	area (km ²)	%study area	%remaining natural vegetation
State owned	20.14	0.86	1.30
Private	33.33	1.43	2.17
State Forests	2.17	0.09	0.14
<u>TOTAL</u>	55.64	2.39	3.62
Mountain Catchment Areas	101.9	4.37	6.62

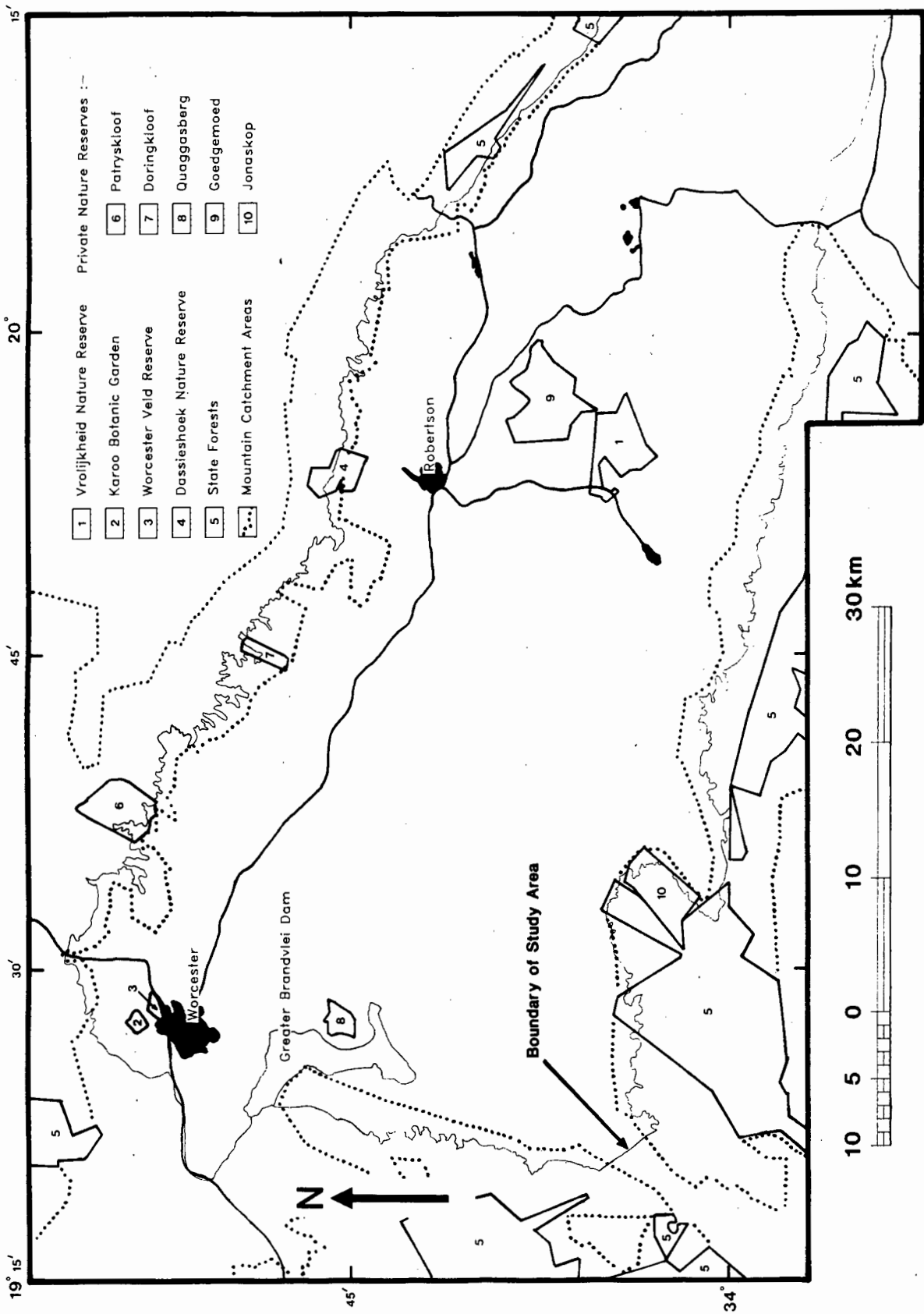


Fig. 5.1: Conserved areas in the Robertson Karoo

reasons are apparent for this, such as lack of funds, and/or limited advice and assistance from the CDNEC etc. An exception is the Quaggasberg Private Nature Reserve, which is to form part of a R60-million country club development (D. van Tubberg pers. comm.). The company coordinating the project intends to employ professional consultants to assess the environmental impact of the intended building operations. The consultants will also facilitate the planning of the resort with the stated objective of conserving the area as a natural ecosystem (A. Marais pers. comm.).

Most of the mountainous area surrounding the Middle Breede River Valley has been declared a Mountain Catchment Area (CDNEC pers. comm.). This area has mostly fynbos vegetation with some karoo - fynbos ecotones. The primary objective of mountain catchment area management is to conserve the mountain ecosystem in such a way as to retain adequate plant cover in order to maintain an optimal yield of high quality water (Wilson 1985). Privately owned land within mountain catchment areas may be used, however, for economic gain such as timber production, grazing, cultivation, fish farming and low intensity recreation, provided it is not in conflict with the primary management objectives (Wilson 1985). Hence the vegetation of mountain catchment areas is not necessarily entirely conserved.

Hilton-Taylor & Le Roux (1989) note that the conservation strategy within the Robertson Karoo is somewhat paradoxical,

since, despite its high number of threatened taxa per unit area and its high percentage of conserved areas (2.39%), many of these taxa do not occur in the nature reserves. This highlights the fact that many of the unique habitats in the Robertson Karoo are not adequately conserved. These include the following: (a) transitional zones on the W and SW side of the valley; (b) wind blown sand communities; (c) river gravels SW of Worcester (totally different to those found at Vrolijkheid) and finally (d) dolomite outcrop zones (B. Bayer pers. comm.).

Up until now, the declaration of existing reserves appears to have been largely on an *ad hoc* basis. The largest provincial reserve, Vrolijkheid Nature Reserve, was originally purchased as a predator control centre in 1958. It was later proclaimed a nature reserve, in 1976, in order to preserve an area classified as Karroid Broken Veld. This reserve conserves the most widespread communities (as defined by Joubert (1968) occurring in the Robertson Karoo, viz. those communities dominated by *Euphorbia mauritanica*, *Pteronia paniculata* and *Elytropappus rhinocerotis*. As such Vrolijkheid has an important role to play because of the necessity of conserving a suite of areas which are representative of the whole of the Robertson Karoo. Without additional future conservation measures, such areas may become the only remnant of the natural vegetation of the Robertson Karoo.

It is clear, therefore, that several high priority habitats of the Robertson Karoo are either not conserved or have inferior

conservation status. The remainder of this chapter discusses ways of broadening the scope of conservation planning in the Robertson Karoo.

5.1.2 Conserving the Robertson Karoo

Hilton-Taylor & Le Roux (1989) note that the Karoo is mainly used as rangeland and conclude that considerable effort should be directed towards correct land use management. It is indicated in Chapter 3, however, that the majority of the Robertson Karoo comprises mainly extremely low quality rangeland. In fact, the major agricultural threat to the vegetation is clearance for cultivated lands, since these provide higher economic benefits. Thus a conservation strategy based on rangeland management would be unlikely to be effective. What is required, therefore, is to establish more reserves in the areas of remaining natural vegetation.

Conservation strategy in the Robertson Karoo should aim to conserve representative samples of both dominant as well as scarce natural ecosystem types (Jarman 1986, UNESCO 1974). This can be achieved at two levels:

a) The conservation of representative samples of the more widespread plant communities. These communities need not be threatened as there is the need to protect familiar areas before they too become extinct. These areas should allow for diversity not only in communities but also in environments.

b) Conserving areas of high conservation potential. The selection of these specific areas should, in theory at least, be based on objective criteria. Margules and Usher (1981) reviewed criteria which have been used for assessing the conservation potential of a particular area. They conclude that "diversity" (both of species and habitats) is the most highly valued criterion followed sequentially by "rarity", "naturalness", "surface area" and the "threat of human interference". These criteria are followed by "representativeness", "potential value", "recorded history", "uniqueness", "ecological fragility" and "management considerations".

This type of baseline data has not been compiled for the vegetation of the Robertson Karoo. The only survey conducted for the Robertson Karoo as a whole was that of Joubert in the 1970's (Chapter 1). This survey, however, mapped plant communities using the dominant plant species and is, therefore, too broad to use as a foundation for producing a detailed conservation plan for the area. There is an need to resurvey the remaining vegetation of the Robertson Karoo in fine detail, taking into account the variations within the communities (as defined by Joubert (1968)) which would indicate highly diverse, scarce and unique habitats.

The present study assesses conservation priority by using the incidence of threatened plant species as a primary criterion. I have two reasons for choosing this emphasis: 1) the importance

and urgency of conserving threatened plant species; 2) the lack of information for the formation of a more comprehensive conservation priority list; and 3) threatened taxa are often good indicators of habitats under threat, since they are normally perceived to be more sensitive to changes in the environment than common, widespread species (Tansley 1988). There is, however, a definition problem regarding the "scale" of a threatened plant species, i.e. a species may be threatened on a local, regional or global scale (Sokolov 1987). A species threatened on a local scale may not necessarily be threatened on a global scale. Thus, there are global and regional Red Data Books ("a true Red Data Book could probably be defined as a register of threatened wildlife that includes definitions of degrees of threat", Scott *et al.* 1987, p.1). Regional Red Data Books have an important role. Listing a species as worthy of Red Data Status, especially on the regional scale, undoubtedly helps in its preservation, since the presence of threatened taxa is an important factor in the designation of protected areas. Regional Red Data Books also focus attention on locally threatened species, promoting research on these species where they are more abundant, and protecting them under harsh conditions at the periphery of their range. This is a vital step towards retaining the genetic diversity of many taxa (Sokolov 1987). For the purpose of this project taxa occurring in the Robertson Karoo threatened on the regional scale (southern Africa) will be studied.

The protection of threatened plant species has been considered the most important function of conservation by the majority of interested parties (Margules & Usher 1981). However Adams & Rose (1978) strongly oppose this bias, stating that there is no simple way to recognize rarity in ecological terms. An international conference at the Royal Botanic gardens at Kew, England in 1975 concluded that special attention should be given to the conservation of threatened floras, especially those which are narrowly endemic and endangered by human activities (Simmons *et al.* 1976).

The term "threatened" is based on the same criteria that Hall & Veldhuis (1985) used for their Red Data book on the Karoo and Fynbos Biomes. Red data ratings were provided for: 1) species restricted to one or few a localized areas not more than a few hundred m² in extent; 2) those that occur fairly widely but at very low frequencies; and 3) those under threat from human pressures such as agriculture, forestry, urban development, flower picking or exploitation for ornamental or medicinal purposes.

The following categories of rarity used for the threatened plant species were based on those recognized by the International Union for the Conservation of Nature and Natural Resources (IUCN, Lucas & Synge 1978):

EXTINCT: Species which no longer exist in the wild, not having been found in repeated searches of all known and likely areas.

ENDANGERED: In immediate danger of extinction if the factors causing its decline continue to operate. Included are those species whose populations have been reduced to a critical level or whose habitats have been so drastically reduced that they are in immediate danger of extinction.

VULNERABLE: Species included here are those likely to move into the Endangered category in the near future if the factors causing the decline continue to operate.

RARE: Species with small world populations or restricted to localized areas or habitats. These are species which are not at present classified as Vulnerable or Endangered.

INDETERMINATE: Species are temporarily grouped here while they are waiting to be placed in one of the above categories when more information becomes available, i.e. it is certain these species are worthy of Red Data Status, although the level of their rarity has not been determined.

UNCERTAIN: Species temporarily grouped here are those for which there is reasonably good, but unconfirmed, grounds for believing them to be threatened; more information is required.

5.1.3 Objectives

The objectives are thus:

- i) To identify taxa, threatened in southern Africa, which occur in the Robertson Karoo.
- ii) To map the locations of threatened plant taxa.
- iii) To identify areas of conservation urgency by assessing relative threats to those areas containing threatened plant

taxa.

5.2 METHODS

5.2.1 Listing threatened plant taxa

A threatened plant species inventory was drawn up for the study area. The list was confined to species in, or bordering on, the study area. In line with this, the Fynbos species bordering on the study area, which occurred at altitudes >2000ft (c 600m) were omitted.

Penny's report (1989) on the threatened plant species of the Breede River, Tulbagh and Hex River Valleys was used as the basis for a preliminary list. Her report was based on the official Red Data Book for threatened plants of the Fynbos & Karoo Biomes (Hall & Veldhuis 1985).

The preliminary list was extensively revised by the author as well as supplemented with information obtained directly from relevant researchers, taxonomists, herbarium records and literature. This included input from C. Hilton-Taylor (pers. comm.), who is currently reviewing the status of threatened species of the Karoo Biome as a whole but without any specific emphasis on the Robertson Karoo.

Many of the problems associated with Red Data species lists have been reviewed by Hall (1981, 1987) and Hall & Veldhuis (1985). A fundamental problem frequently encountered is variable accuracies regarding the taxonomy of each group. Certain of the

groups, for example *Drosanthemum* and *Lightfootia* have been poorly assessed and the only available information is in the form of early monographs of dubious authenticity.

A second major problem is the accuracy of herbarium records and whether they reflect the exact distribution and the abundance of species. Such records reflect the collecting patterns at a general level often showing only limited correlation with the distribution and abundance of particular plant species. Moreover, individual species are subject to widely varied levels of collecting pressure, depending on the accessibility of the area, how readily the plant species may be found (Gibbs Russell 1985) and the interest value of the plant in question. For instance *Stapeliopsis breviloba* is extremely difficult to find as result of its cryptic habitat. Therefore, its Red Data status may be incorrect, perhaps simply being an artefact of under-collection (P. Bruyns pers. comm.). Also certain annual species which flower outside the main flowering season, Spring, are usually under-collected (D. Snijman pers. comm.). Furthermore, there are also likely to be many undescribed species which are not recorded in herbaria at all. Thus the list of Red Data taxa could markedly underestimate the number of threatened species occurring in the area.

It was possible to overcome certain of the above problems, especially those of preferential collection in certain areas. This was achieved, in part, by personal communication with

researchers having the appropriate specialized field knowledge of the study area (in particular B. Bayer, Worcester Veld Reserve; P. Perry, Karoo Botanic Garden). Other problems were minimized as the inventory was updated in discussion with other researchers and in reviewing the literature. Any Red Data list is in need of constant revision, with new information always being added to update systematic data and Red Data status.

An additional problem arises with delimiting the exact map locations of the Red Data species, as many of the place names have changed subsequent to collection, or the precise locality was never recorded. As a result, the locations of several of the taxa could not be mapped while others could only be pinpointed to an area of 1-2 km².

5.2.2 Priority conservation areas

The priority conservation ratings, which were purely qualitative, were assigned to areas containing clusters of threatened plant taxa, as habitats having high concentrations of threatened taxa have a high probability of being rare or vulnerable (Tansley 1988). Thus priority conservation ratings for the area were based on two criteria, firstly the number of threatened plant taxa in a particular site and secondly the degree of human threat from agricultural expansion, urbanization and mining. Information on the agricultural threat was obtained from Chapter 4. The threat from urban expansion is centered around the municipal area of Worcester (see Chapter 3), whereas the threat from mining is at present confined to two areas,

Langevlei and Brewelskloof (Chapter 3). The areas containing more than four Red Data taxa were given the highest priority ratings, because these presumably indicate the presence of threatened habitats. These areas were further rated on the number of taxa and if they were threatened by human influence. The next set of priority areas were those containing between one and three taxa. These were similarly rated. Priority was then given to areas containing one threatened taxon. These were rated on a) number of locations where it has been collected and b) if it is endemic to the study area. Within each rated group, the areas were ordered according to rarity status. Finally areas containing taxa which had already been recorded in higher priority areas or occurred in nature reserves. A problem is that the priority conservation areas can only take into account those areas which are known locations of threatened taxa - it ignores areas containing threatened taxa which are either unmappable or have not actually been collected before and thus remain unrecorded.

5.3 RESULTS AND DISCUSSION

5.3.1 Threatened plant taxa

Of the 61 threatened plant taxa occurring in the Robertson Karoo, 8 are described as endangered, 20 are rare, 8 are vulnerable, 3 are indeterminate and 22 are uncertain (Table 5.2). At least 6 of the threatened taxa are reported from only one locality and it was further found that 83% of the threatened taxa are endemic to the Middle Breede River Valley

Table 5.2: Threatened plant taxa of the Robertson karoo

* Lists the threatened taxa occurring in the study area as defined in section 1.4.1. Fynbos taxa bordering on the study area and occurring at altitudes >2000ft (c600m) were omitted.

* Lists taxa together with:

i) species number - this no. corresponds to Fig. 5.3

ii) original source where the information was obtained

iii) IUCN Status and reference

iv) Map location and mapping precision:- (U) = unmappable; (A) = taxa is mapped to a particular area, e.g. The Nekkie's region; (K) = mapped to within 1-2km radius; (P) = precise location, within 1km radius.

Unless followed by a date, the references are personal communications.

* More detailed information on certain of the taxa is presented in Appendix 1.

Taxa name	Original Source	Status (Reference)	Map Location (Grid Reference, Description Mapping Precision)
PTERIDOPHYTA			
OPHIOGLOSSACEAE			
1 <i>Ophioglossum nudicaule</i> L.f.	C. Hilton-Taylor	Rare (C. Hilton-Taylor)	3319 C (U)
ANGIOSPERMAE - NONCOTYLEDONAE			
AMARYLLIDACEAE			
2 <i>Haemanthus sanguineus</i> Jacq. (pink)	B. Bayer P. Perry D. Snijman	Rare (G. Duncan P. Perry, B. Bayer)	3319CB SW Worcester (P)
3 <i>Merine</i> cf. <i>pudica</i> Hooker f. (<i>Merine</i> sp. nov.)	P. Perry	Uncertain (C. Hilton-Taylor)	3319CB Karoo Botanic Garden (P) 3319CB Brewelskloof (P) 3319CB Brandvlei (The Nekkie)
ASPHODELACEAE			
4 <i>Haworthia magnifica</i> V. Poelln. var. <i>notabilis</i> (V. Poelln.) Bayer	B. Bayer C. McDowell	Rare (B. Bayer)	3319DC Wolwekloof (K)
5 <i>Haworthia marginata</i> (Lam.) Stearn	B. Bayer C. Hilton-Taylor	Endangered (B. Bayer C. McDowell)	3320CC Ashton (K) 3320CC/3420AA Koppies E of road from Drew (K)
6 <i>Haworthia mutica</i> Haw.	B. Bayer	Vulnerable (C. Hilton-Taylor)	3320CC N Breede River at Drew (K)
7 <i>Haworthia poelnitziana</i> Uitew.	B. Bayer	Endangered (C. Hilton-Taylor)	3320CC W Drew (P)
8 <i>Haworthia pubescens</i> Bayer	B. Bayer	Vulnerable (C. Hilton-Taylor)	3319DA/3319CB Sandberg hills (K) 3319CB SE Brandvlei Dam (K) 3319CD S Lemoenpoort (K)

9	<i>Poellnitzia rubriflora</i> (L. Bolus) Uitew.	B. Bayer P. Perry C. McDowell	Vulnerable (C. Hilton-Taylor)	3319DD Vrolijkheid (K) 3320CC 7miles N Stormsvlei (P) 3319DD SW Robertson (P) 3319DD N Poesjenelsrivier (K) 3320CC Bonnievale (K)
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CYPERACEAE

10	<i>Scirpus delicatulus</i> Levyns	A. Penny	Indeterminate (Hall & Veldhuis 1985)	3319CB (U)
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HYACINTHACEAE

11	<i>Albuca</i> sp. nov. (<i>scabra</i> nom. nud. in ms.)	B. Bayer	Uncertain (C. Hilton-Taylor)	3320CC/3420AA Drew (K)
12	<i>Lachenalia moniliformis</i> W.F. Barker	P. Perry	Rare (C. Hilton-Taylor G. Duncan) Endangered (P. Perry)	3319CD Lemoenpoort (A)
13	<i>Lachenalia physocaulos</i> W.F. Barker	G. Duncan	Rare (G. Duncan)	3319DD Buitenstekloof (K)
14	<i>Neopatersonia uitenhagensis</i> Schonl.	B. Bayer	Rare (Hall & Veldhuis 1985)	3319DD Buitenstekloof (K)

IRIDACEAE

15	<i>Chasmanthe bicolor</i> (Gasp.) N.E. Br.	Q. Hahndick	Uncertain (Hall & Veldhuis 1985)	3319DD Vrolijkheid (K)
16	<i>Geissorhiza geminata</i> E. Meyer ex Baker	A. Penny	Uncertain (Hall & Veldhuis 1985)	3319CB Brandvlei Dam (A) 3319CD Moordkuil, Worcester (K) 3319DC Scherpenheuvel vlei (K)
17	<i>Gladiolus virescens</i> Thunb. var. <i>roseo-venosus</i> Lewis	A. Penny	Indeterminate (C. Hilton-Taylor) Rare (G. Duncan P. Perry)	3319CB Brandvlei Hills (K) 3319CB Kweekkraal, Worcester (P) 3319CD Doorn rivier (K) 3318CB Quaggasberg (A)
18	<i>Ixia campanulata</i> Houtt.	P. Perry	Indeterminate (Hall & Veldhuis 1985)	3319CB NW Worcester (P)
19	<i>Ixia collina</i> Goldbl. & Snijman	C. Hilton-Taylor	Rare (G. Duncan, C. Hilton-Taylor)	3319DA Breede river, SE Worcester (K)
20	<i>Ixia pumilio</i> Goldbl. & Snijman	C. Hilton-Taylor	Rare (C. Hilton-Taylor)	3319CB Reiers Rus Farm, S Worcester (P)

21	<i>Ixia vanzylliae</i> L. Bolus	C. Hilton-Taylor	Rare (C. Hilton-Taylor)	3320CC Bonnievale (U)
22	<i>Ixia</i> sp. nov.	D. Snijman	Uncertain (C. Hilton-Taylor)	3319CB NW Karoo Botanic Garden
23	<i>Lapeirousia plicata</i> (Jacq.) Diels subsp. <i>effurcata</i> (Lewis) Goldbl.	C. Hilton-Taylor	Uncertain (C. Hilton-Taylor)	3319DA 10 miles from Worcester on Robertson road (P)
24	<i>Moraea worcesterensis</i> Goldbl.	B. Bayer, P. Perry C. Hilton-Taylor J. Forrester	Endangered (C. Hilton-Taylor)	3319CB W Worcester Veld Reserve (P)
25	<i>Sessilistigma radians</i> Goldbl.	C. Hilton-Taylor	Vulnerable (C. Hilton-Taylor)	3319DD N foothills Riversonderend Berge (U) 3319DD Turn off to Steenbokvlakte between Stormsvleikloof & McGregor (P) 3320CC Near Ashton (K)

ANGIOSPERMAE - DICOTYLEDONAE

ASCLEPIADACEAE

26	<i>Ceropegia connivens</i> R.A. Dyer	C. McDowell	Uncertain (Hall & Veldhuis 1985)	3319DA Tweefontein, Worcester (P) 3319DA 1.5km W Mowers Siding (P)
27	<i>Ceropegia occulta</i> R.A. Dyer	C. McDowell	Rare (Dyer 1983)	3319DA Tweefontein, Worcester (P) 3319DB Buitenstekloof (K)
28	<i>Duvalia caespitosa</i> (Masson) Haw.	P. Bruyns	Rare (P. Bruyns)	3319DD From Rooiberg to just before Kogmanskloof on the Worcester-Robertson road (U)
29	<i>Stapelia scitula</i> Leach.	C. McDowell	Rare (P. Bruyns)	3319DB Buitenstekloof (K) 3319DD Rooiberg, Robertson (K)
30	<i>Stapeliopsis breviloba</i> (R.A. Dyer) Bruyns	A. Penny	Uncertain (P. Bruyns)	3319DA Near turn-off to Elandia on Worcester-Robertson road (K) 3319CD Lemoenpoort (K) 3319DA Moordkuil (K)

ASTERACEAE

31	<i>Athanasia crassifolia</i> Schltr. ined.	A. Penny	Uncertain (Hall & Veldhuis 1985)	3319CB Brandvlei Hills (A)
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32 *Senecio rehmannii* Bolus A. Penny Uncertain 3319CB (U)
(Hall & Veldhuis 1985)

CAMPANULACEAE

33 *Lightfootia effusa* Adamson A. Penny Uncertain 3319DC Poesjeneisrivier (P)
(Hall & Veldhuis 1985)

CRASSULACEAE

34 *Crassula* sp. nov. B. Bayer Uncertain 3319CD Haumansberg (K)

ERICACEAE

35 *Grisebachia rigida* A. Penny Vulnerable 3319CB E Kwaggaskloof Dam (K)
N. E. Br. (Hall & veldhuis 1985) 3319CD Surrounding Kwaggaskloof
Dam (A)
3319CD/3319DC S Breede River (K)
3319CB Onder Brandvlei (K)

FABACEAE

36 *Aspalathus burcheiliana* A. Penny Vulnerable 3319DD Breede river eastern bank
Benth. (Hall & Veldhuis 1985) at Upper Ford, Swellendam (U)

37 *Aspalathus macrocarpa* A. Penny Uncertain 3319DD Langeberg foothills
Ecklon & Leyher (Hall & Veldhuis 1985) (altitude c400m) near
De Hoop farm, Robertson (K)
"Wagenmakersbosch",
Swellendam (U)

38 *Polhillia waltersii* P. Perry Vulnerable 3319CB Worcester municipality (P)
(Stirton) Stirton ined. (C. Hilton-Taylor) 3319CB Worcester airfield (P)

GERANIACEAE

39 *Pelargonium* sp. nov. B. Bayer Rare (B. Bayer) 3319CB Worcester (P)

HESENBRYANTHEACEAE

40 *Drosanthemum bellum* L. Bolus B. Bayer Rare (B. Bayer) 3319CB Brandvlei Dam (A)

41 *Drosanthemum hallii* L. Bolus B. Bayer Rare (B. Bayer) 3319CB N Brandvlei Dam (A)

42 *Drosanthemum micans* P. Perry Uncertain 3319CB Karoo Botanic Garden (P)
(L.) Schwantes

43 *Drosanthemum thudichumii* B. Bayer Rare (B. Bayer) 3319CB Karoo Botanic Garden (P)
L. Bolus

44	<i>Gibbaeum esterhuyseniae</i> L. Bolus	B. Bayer	Extinct? (Hall & Veldhuis 1985)	34198B Between McGregor & Stormsvleikloof (U) 3420AA between Bonnievale & Stormsvleikloof (U)
45	<i>Lampranthus arbutnotiae</i> (L. Bolus) L. Bolus	A. Penny	Uncertain (Hall & Veldhuis 1985)	3319CB (U)
46	<i>Lampranthus aurantiacus</i> (DC.) Schwant.	P. Perry	Uncertain	3319CD Moddergat, Worcester (K)
47	<i>Lampranthus vanzijliae</i> (L. Bolus) N. E. Br.	B. Bayer	Endangered (B. Bayer)	3319CB Breede river flats, Worcester (A)
48	<i>Ruschia amicomum</i> (L. Bolus) Schwantes	A. Penny	Rare (C. Hilton-Taylor)	3319DC Dublin farm, Worcester (K)
49	<i>Ruschia leipoldtii</i> L. Bolus	A. Penny	Endangered (C. Hilton-Taylor)	3319DD N NW Robertson (K) 3319DD McGregor & Stormsvleikloof (U)

OXALIDACEAE

50	<i>Oxalis dregei</i> Sonder	B. Bayer	Rare (B. Bayer)	3319CB SW Worcester (K)
51	<i>Oxalis natans</i> L.f.	B. Bayer	Rare (B. Bayer)	3319CB (U)
52	<i>Oxalis</i> sp. nov.	B. Bayer	Uncertain (B. Bayer)	3319CD Haumansberg, Worcester (K)

PROTEACEAE

53	<i>Leucadendron chamaelaea</i> (Lam.) I.J. Williams	A. Penny	Endangered (S. Brown 1988)	3319CB E Brandvlei Dam (K)
54	<i>Leucadendron flexuosum</i> I.J. Williams	A. Penny	Endangered (S. Brown 1988)	3319CB W Worcester (P)
55	<i>Leucospermum utriculosum</i> Rourke	J. Rourke	Rare (J. Rourke)	3319DD Sandberg, Robertson (A) 3420AA Stormsvlei Hills (A) 3319DC 1 mile from Worcester- Robertson road, Elandia (P)
56	<i>Protea restionifolia</i> (Salisb. ex J. Knight) Rycr.	B. Bayer	Vulnerable (S. Brown 1988)	3319CB N Brandvlei Dam (A)

ROSACEAE

57	<i>Cliffortia carinata</i> Weim.	A. Penny	Uncertain (Hall & Veldhuis 1985)	3319DC Poesjenelsrivier (P)
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RUTACEAE

- 58 *Agathosma stipitata* Pill. A. Bean Uncertain 3319DC Jonaskop, Boesmanskloof (A)
3319CB Brandvlei Berg (K)
- 59 *Euchaetis pungens* A. Penny Uncertain 3319DC/DA Moordkuil, Worcester (K)
(Bartling & Wendl.) 3319CD S Kwaggaskloof Dam (P)
I.J. Williams 3319CB Brandvlei Berg (K)

SCROPHULARIACEAE

- 60 *Nemesia pageae* L. Bolus A. Penny Uncertain 3319CB W Worcester Veld Reserve (P)
(Hall & Veldhuis 1985) 3319CB Karoo Botanic Gardens (P)
3319CD Moddergat, Worcester (K)
3319DA 5-6miles on Worcester-
Robertson road at
Elandia turn-off (P)
3319DB Buitenstekloof (K)
- 61 *Sutera cephalotes* Kuntze A. Penny Uncertain 3319CB Brandvlei Hills (A)
(Hall & Veldhuis 1985)
-

(Table 5.2. & 5.3).

The map locations (Fig. 5.3) of the threatened taxa (presented as an overlay to the potential agricultural, urban (located within Worcester municipality) and mining (located in vicinity of quarries) threat, Fig. 5.2) reveal that the majority of the taxa occur on recent alluvial deposits (see Fig. 4.1). Such deposits, which underlie the drainage patterns of the major rivers in the Robertson Karoo, are selectively cultivated because of their close proximity to a water source (See Chapter 4). This selective cultivation is likely to represent the key cause for the threatened status of many of these plant taxa and their associated low lying communities. A large number of threatened taxa also occur on Bokkeveld shales. These shales are associated with fertile soils, e.g. Hutton soil form, and much diminished remnants of the vegetation threatened by future agricultural expansion (high agricultural threat, Table 4.3.).

Fig. 5.3 also illustrates clearly defined clusters of threatened plant taxa. More than 50% of the taxa are located west of the line of longitude $19^{\circ}30'$ in a vegetation type which is transitional from Karoo through Renosterveld to Fynbos. In fact, Robertson Karoo appears to have a high density of threatened taxa mainly because of the incidence of these plants within the ecotonal habitats. Only 39% of the plant taxa listed occur in true Karroid Broken Veld and the majority of these taxa are restricted to rare and localized habitats, e.g. dolomite outcrops of Buitenstekloof. Furthermore, only 11.5% of the

Table 5.3: Plant taxa endemic to the Middle Breede River Valley.

MONOCOTYLEDONAE

Amaryllidaceae

Haemanthus sanguineus Jacq. (pink variety)

Asphodelaceae

Haworthia herbacea (Mill.) Stearn

Haworthia magnifica var. *notabilis* (V. Poelln.) Bayer

Haworthia mutica Haw.*

Haworthia pubescens Bayer

Poellnitzia rubriflora (L. Bolus) Uitew.

Eriospermaceae

Eriospermum bowieanum Baker

Hyacinthaceae

Albuca sp. nov.

Lachenalia moniliformis W. F. Baker

Lachenalia physocaulos W. F. Baker

Lachenalia stayneri W. Baker

Iridaceae

Gladiolus virescens Thunb. var. *roseo-venosus* Lewis

Ixia collina Goldbl. & Snijman

Ixia pumilio Goldbl. & Snijman

Ixia patens Aiton

Ixia vanzylliae L. Bolus

Ixia sp. nov.

Moraea worcesterensis Goldbl.

Sessilistigma radians Goldbl.

DICOTYLEDONAE

Asclepiadaceae

Ceropegia connivens R.A. Dyer

Ceropegia occulta R.A. Dyer

Duvalia caespitosa (Masson) Haw.

Stapelia scitula Leach.

Stapeliopsis breviloba (R.A. Dyer) Bruyns

Campanulaceae

Lightfootia effusa Adamson

Crassulaceae

Crassula sp. nov.

Ericaceae

Grisebachia rigida N.E. Br.

Euphorbiaceae

Euphorbia nesemannii R.A. Dyer

Fabaceae

Aspalathus burchelliana Benth.

Aspalathus macrocarpa Ecklon & Zeyhar

Polhillia waltersii (Stirton) Stirton ined.

Geraniaceae

Pelargonium sp. nov.

Mesembryanthemaceae

Drosanthemum bellum L. Bolus

Drosanthemum hallii L. Bolus

Drosanthemum micans (L.) Schwantes

Drosanthemum speciosum (Haw.) Schwantes

Drosanthemum thudichumii L. Bolus

Gibbaeum esterhuyseniae L. Bolus

Lampranthus vanzijliae (L. Bolus) N.E. Br.

Oxalidaceae

Oxalis sp. nov.

Oxalis viscidula Schltr.

Proteaceae

Leucadendron flexuosum I.J. Williams

Rutaceae

Agathosma stipitata Pill.

* This species may also occur south of Swellendam outside the study area.

The above taxa have only been recorded from the middle Breede River valley. However, this limited distribution may in some cases be a function of under-collection.

A) Threatened plant taxa of the Robertson Karoo

- 1 *Ophioglossum nudicula* L.f.
- 2 *Haemanthus sanguineus* Jacq. (pink)
- 3 *Nerine cf. pudica* Hooker f. (*Nerine* sp. nov.)
- 4 *Haworthia magnifica* V. Poelln, var. *notabilis* (V. Poelln) Bayer
- 5 *Haworthia marginata* (Lam.) Stearn
- 6 *Haworthia mutica* Haw.
- 7 *Haworthia poelinitziana* Uitew.
- 8 *Haworthia pubescens* Bayer
- 9 *Poelinitzia rubriflora* (L. Bolus) Uitew.
- 10 *Scirpus delicatulus* Levyns
- 11 *Albica* sp. nov. (*scabra* nom. nud. in ms.)
- 12 *Lachenalia moniliformis* W.F. Barker
- 13 *Lachenalia physocaulos* W.F. Barker
- 14 *Neopaterersonia vitenhagensis* Schönl.
- 15 *Chasmanthe bicolor* (Gasp.) N.E. Br.
- 16 *Geissorrhiza geminata* E. Meyer ex Baker
- 17 *Gladolius virescens* Thunb. var. *roseo-venosus* Lewis
- 18 *Ixia campanulata* Houtt.
- 19 *Ixia collina* Goldbl. & Snijman
- 20 *Ixia pumilio* Goldbl. & Snijman
- 21 *Ixia vanzylliae* L. Bolus
- 22 *Ixia* sp. nov.
- 23 *Lapeirousia plicata* (Jacq.) Diels subsp. *effurcata* (Lewis) Goldbl.
- 24 *Araea worcesterensis* Goldbl.
- 25 *Sessilistigma radicans* Goldbl.
- 26 *Ceropegia connivens* R.A. Dyer
- 27 *Ceropegia occulta* R.A. Dyer
- 28 *Duvallia caespitosa* (Masson) Haw.
- 29 *Stapelia scitula* Leach.
- 30 *Stapeliopsis breviflora* (R.A. Dyer) Bruyns
- 31 *Athenasia crassifolia* Schltr. ined.
- 32 *Senecio rehmannii* Bolus
- 33 *Lightfootia effusa* Adamson
- 34 *Crassula* sp. nov.
- 35 *Grisebachia rigida* M. E. Br.
- 36 *Aspalathus burckelliana* Benth.
- 37 *Aspalathus macrocarpa* Ecklon & Zeyher
- 38 *Polhillia waltersii* (Stirton) Stirton ined.
- 39 *Pelargonium* sp. nov.
- 40 *Drosanthemum bellum* L. Bolus
- 41 *Drosanthemum hallii* L. Bolus
- 42 *Drosanthemum micans* (L.) Schwantes
- 43 *Drosanthemum thudichumii* L. Bolus
- 44 *Gibbaeum esterhuyseniae* L. Bolus
- 45 *Lampranthus erubescens* (L. Bolus) L. Bolus
- 46 *Lampranthus aurantiacus* (DC.) Schwant.
- 47 *Lampranthus vanziifolia* (L. Bolus) M. E. Br.
- 48 *Ruschia amicornum* (L. Bolus) Schwantes
- 49 *Ruschia leipoldtii* L. Bolus
- 50 *Oxalis dregei* Sonder
- 51 *Oxalis natans* L.f.
- 52 *Oxalis* sp. nov.
- 53 *Leucadendron chameleae* (Lam.) I.J. Williams
- 54 *Leucadendron flexuosum* I.J. Williams
- 55 *Leucospermum utriculosum* Rourke
- 56 *Protea restionifolia* (Salisb. ex J. Knight) Rycr.
- 57 *Cliffortia carinata* Wein.
- 58 *Agathosma stipitata* Pill.
- 59 *Euchaetis pungens* (Bartling & Wendl.) I.J. Williams
- 60 *Nemesia pageae* L. Bolus
- 61 *Sutera cephalotes* Kuntze

B) Priority conservation areas of the Robertson Karoo

- A W & S Brandvlei & Kwaggaskloof Dams
- B Breede Floodplain
- C Buitenstekloof
- D Haumansberg/Lemoenpoort
- E The Nekklies Hills
- F Drew.
- Poesjensrivier
- NW Robertson

AREAS CONTAINING A SINGLE TAXON UNDER THREAT

- G Taxon recorded from one locality
- H Taxon endemic to the study area
- I Taxon not endemic to the study area

J Tweefontein

AREAS CONTAINING A SINGLE TAXON NOT UNDER THREAT

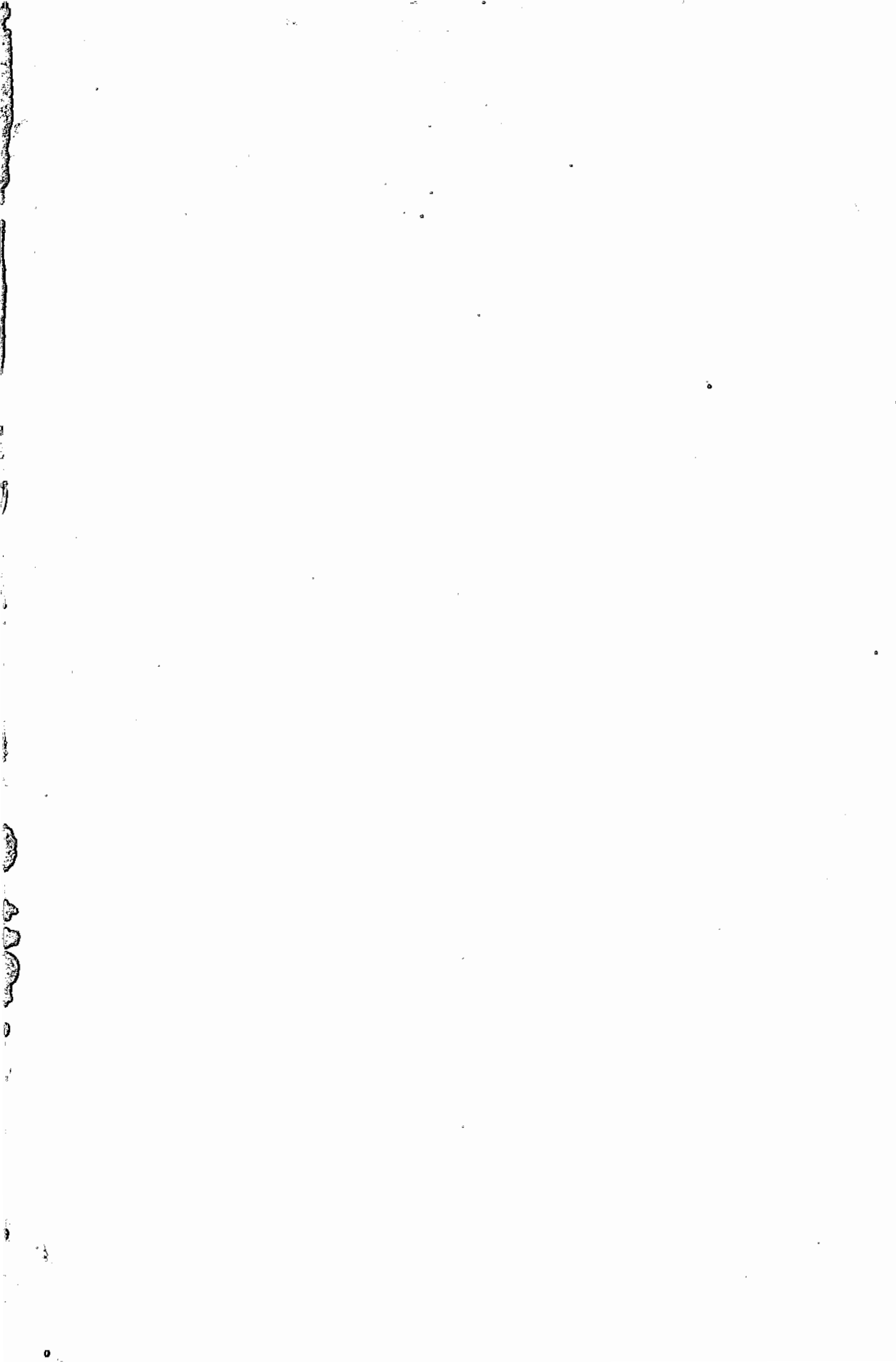
- K Endemic taxa

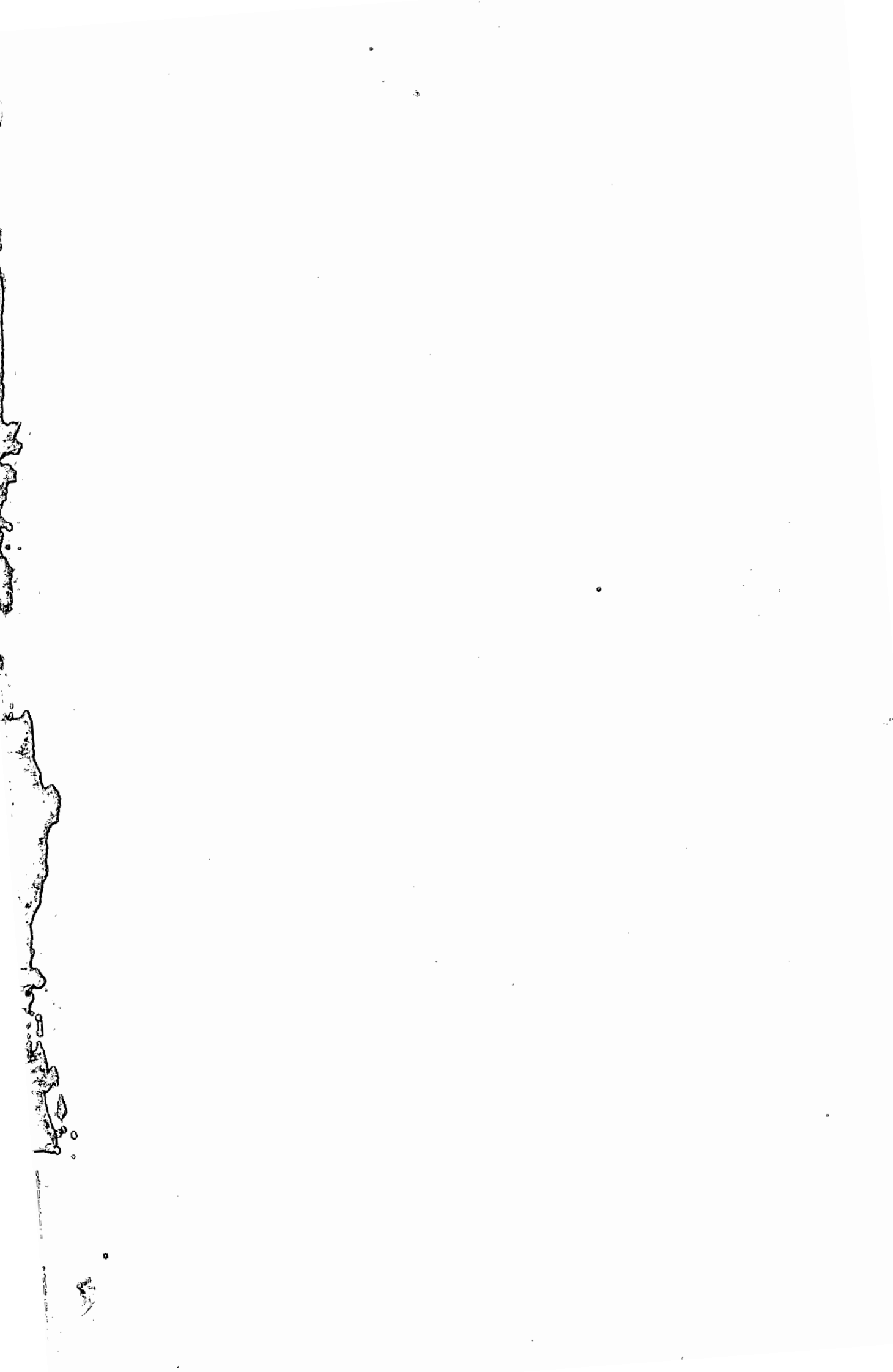
AREAS CONTAINING TAXA WHICH HAVE ALREADY BEEN

- RECORDED IN A HIGHER PRIORITY AREA OR OCCUR IN A RESERVE
- L Taxa occur in a higher priority area
- M Taxa occur in a conserved area

N Conserved areas:-

- W Worcester
- Quaggasberg
- Karoo Botanic Gardens
- Vrolijkheid





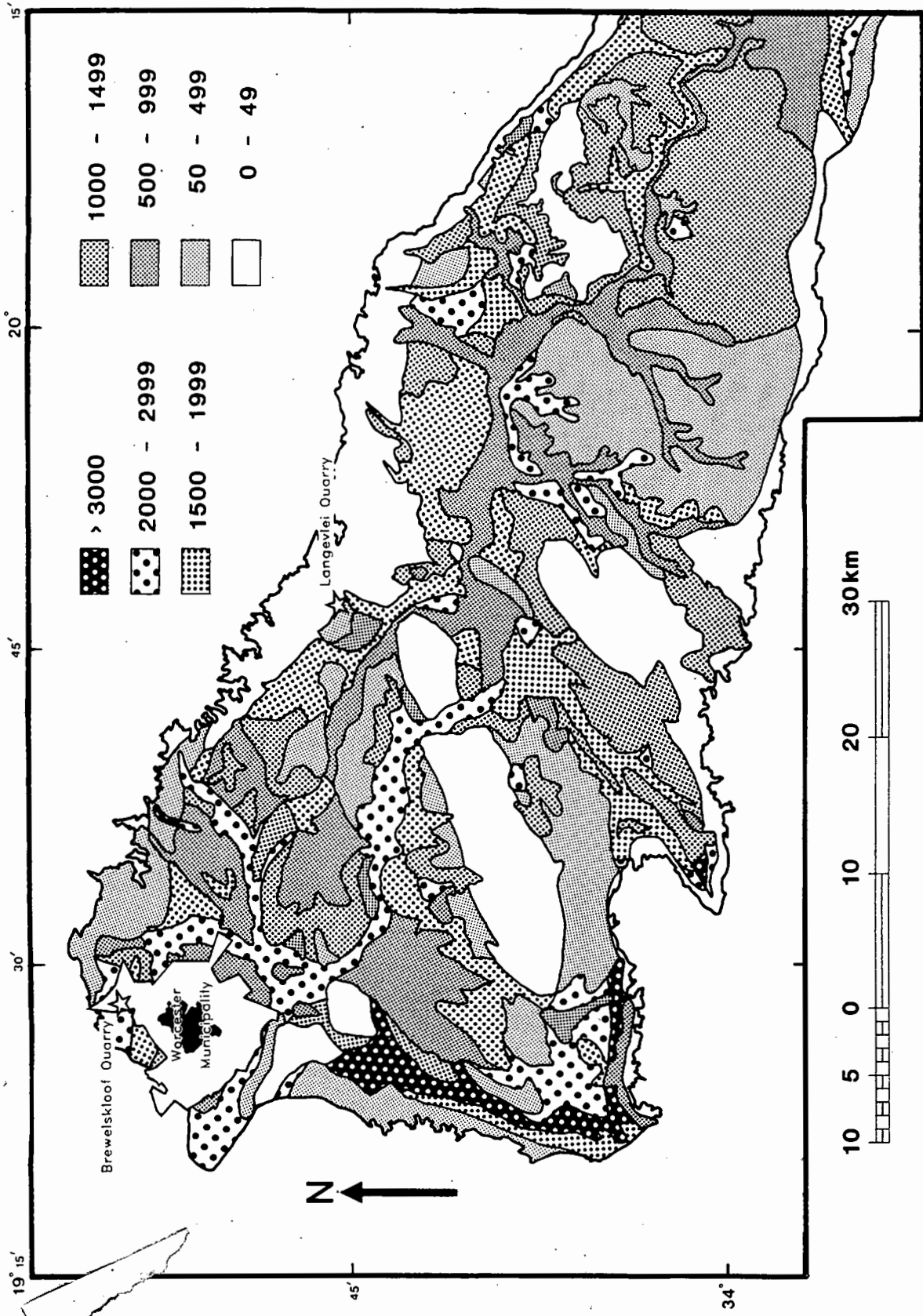


Fig. 5.2: Agricultural, urban and mining threats to the vegetation

threatened taxa are actually known to be present in existing nature reserves. This provides further evidence for the poor conservation status of the Robertson Karoo at least as far as plant taxa are concerned.

5.3.2 Priority conservation areas

The priority areas are rated from A-0 (Table 5.5) and graphically presented as an overlay to the map of the threatened plant taxa (Fig. 5.3).

The highest Priority Area (Priority Area A, Table 5.4, Fig. 5.3) is in the vicinity of Brandvlei Dam. This area, which has a high agricultural threat index (>3000, Fig. 5.2) and is also threatened by alien infestations (Table 5.4), apparently contains an unique inland strandveld-type vegetation (P. Perry, pers. comm.). However, with the exception of *Gladiolus virescens* var. *roseo-venosus* which is classified as "intermediate", the threatened taxa in this area have "uncertain" rarity status. Prioritized simply on the basis of its threatened plant taxa status, this area may not be considered highly valuable. There is a need to assess the threatened status and extent of the natural ecosystem in greater depth to establish its true conservation value. It is also vital to investigate the current incidence of threatened taxa to ascertain whether they warrant Red Data status and in fact, whether other as yet unclassified, less obvious, species are in need of Red Data status. It is worth-while to note that many of the threatened plant taxa recorded in this area were collected earlier this century and

Table 5.4: Priority conservation areas

Area	No. threatened taxa	Threats	Ownership	Taxa + rarity status*
A W & S Brandvlei Kwaggaskloof Dams	6	alien infestations agricultural expansion	Dept. Prisons	I <i>Gladiolus virescens</i> var. <i>roseo-venosus</i> U <i>Geissorhiza geminata</i> U <i>Atnanasia crassifolia</i> U <i>Grisebacia rigida</i> U <i>Euchaetis pungens</i> U <i>Sutera cephalotes</i>
B Breede Floodplain	5	alien infestations, agricultural expansion, urbanization	Private, Worcester Municipality	E <i>Lampranthus vanzijliae</i> V <i>Poihilia waitersii</i> R <i>Haemanthus sanguineus</i> R <i>Oxalis dregei</i> R <i>Pelargonium</i> sp. nov.
C Buitenstekloof	5	mining	Private	R <i>Stapelia scitula</i> R <i>Neopatersonia uitenhagensis</i> R <i>Lachenalia physocaulos</i> U <i>Nemesia pageae</i> U <i>Ceropegia occulta</i>
D Haumansberg/ Lemoenpoort	5	-	Private	R <i>Lachenalia moniliformis</i> V <i>Haworthia pubescens</i> R <i>Oxalis natans</i> U <i>Stapeliopsis breviloba</i> U <i>Crassula</i> sp. nov.
E The Nekkie	4	-	Private	V <i>Protea restionifolia</i> R <i>Drosanthemum bellum</i> R <i>D. hallii</i> U <i>Nerine</i> sp. nov.
F Drew	2	agricultural expansion	Private	E <i>Haworthia doebnitziana</i> U <i>Albuca</i> sp. nov.
Poesjenelsrivier	2	agricultural expansion	Private	U <i>Lightfootia effusa</i> U <i>Cliffortia carinata</i>
G NW Robertson	2	-	Private	E <i>Ruschia leipoldtii</i> R <i>Haworthia magnifica</i> var. <i>notabilis</i>

AREAS CONTAINING A SINGLE TAXON

H Taxa recorded from one locality:-

3319CB W Worcester Veld Reserve	urbanization	Municipality	E <i>Moraea worcesterensis</i>
3319CB W Worcester	urbanization	Private	E <i>Leucodendron flexuosum</i>
	alien infestations		
3319DA Breede River, SE Worcester	agricultural expansion, alien infestations	Private	R <i>Ixia coilina</i>
3319CB Reirsrus, Worcester	"	Private	R <i>Ixia dumilio</i>
3319CB NW Karoo Botanic Garden	agricultural expansion	Private	U <i>Ixia</i> sp. nov.

I Taxa endemic to the study area:-

3320CC Ashton/3420AA Drew	agricultural expansion	Private	E <i>Haworthia marginata</i>
3320AA Drew	"	Private	V <i>Haworthia mutica</i>

J Taxa not endemic to the study area:-

3319CB E Brandvlei Dam	agricultural expansion	Private	E <i>Leucodendron chamaelaea</i>
3319DD Steenbokvlakte/3320CC Ashton	"	Private	V <i>Sessilistigma radians</i>
3319CB NW Worcester	"	Private	I <i>Ixia campanulata</i>
3319CD Moddergat (2 taxa)	"	Private	U <i>Lampranthus aurantiacus</i>
	"	"	U <i>Nemesia pageae</i>
3319DA on rd from Worcester to Robertson	"	Private	U <i>Lapeirousia plicata</i> subsp <i>effurcata</i>

K Tweefontein (2 taxa)

agricultural expansion	Private	U <i>Ceropegia connivens</i>
		U <i>Ceropegia occulta</i>

AREAS CONTAINING A SINGLE TAXON NOT UNDER THREAT

L Endemic taxa

3319DD Sandberg, Robertson/ 3319DC Elandia/ 3420AA Stomsvlei hills	- - -	Private " "	R <i>Leucospermum utriculosum</i> " "
3319DD N Robertson	-	Private	U <i>Aspalathus macrocarpa</i>
3319DC Jonaskop/ 3319CB Brandvei	- -	Private "	U <i>Agathosma stipitata</i> "

AREAS CONTAINING TAXA WHICH HAVE ALREADY BEEN RECORDED IN A HIGHER PRIORITY AREA OR OCCUR IN A RESERVE

M Taxa occurs in a higher priority area:-

Elandia (2 taxa)	Private	U <i>Nemesia pageae</i> U <i>Stapeliopsis breviflora</i>
3319CB Sandberg hills/ 3319CD SE Brandvlei Dam	Private	V <i>Haworthia pubescens</i>
3319CD Surrounding Kwaggaskloof Dam	Private Dept. Prisons	V <i>Grisebachia rigida</i>
3319DD Rooiberg, Robertson	Private	R <i>Stapelia scitula</i>
3319DC/DA Moordkuil	Private	I <i>Eucnaetis pungens</i>
3319CB Moordkuil, Worcester/ 3319DA Scharpenheuvel vlei	Private	U <i>Geissorhiza geminata</i>

M Taxa occurs in a conserved area:-

3320CC N Stormsvlei/ 3320CC Bonnievale/ 3319DD SW Robertson/ 3319DB N Poesjenelsrivier	Private " " "	V <i>Poellnitzia rubriflora</i> " " "
3319CD Kweekkraal/ 3319CD Doorn River/ 3319CB Onder Brandvlei	Dept. Prisons Private "	I <i>Gladiolus virescens</i> var <i>roseo-venosus</i> "
3319CB Brewelskloof	Municipality	U <i>Merine</i> sp nov

O Conserved areas

W Worcester	1	Municipality	V <i>Polhilia waitersii</i>
Quaggasberg	1	Private	I <i>Gladiolus virescens</i> var. <i>roseo-venosus</i>
Karoo Botanic Gardens	4	National Botanic Gardens	R <i>Drosanthemum micans</i> R <i>D. thudichumii</i> U <i>Merine</i> sp nov U <i>Nemesia pageae</i>
Vrolijkheid	2	Provincial	V <i>Poellnitzia rubriflora</i> U <i>Chasmanthe bicolor</i>

* The rarity status is abbreviated:

- E = endangered
- R = rare
- V = vulnerable
- I = indeterminate
- U = uncertain

may already be extinct from this locality, e.g. *Athanasia crassifolia*, *Grisebachia rigida*.

Priority Area B, the Breede River floodplain, is of importance because it is possibly the only remnant of what was once an extensive floodplain stretching the length of the valley (see Chapter 2). This area is at present under threat from agricultural expansion, alien infestations and urbanization. However, as the area is relatively marshy, the threat from urban expansion is consequently lower. Possibly the greatest immediate threat in this area is the alien infestations, especially of *Sesbania* (B. Bayer pers. comm.).

Priority Area C is situated in close proximity to a limestone quarry (Fig. 5.2. & 5.4.). The natural plant community of this area is confined to granite outcrops which overlay the dolomite deposits which are much in demand for cement and lime (McDowell, pers. comm.). This rare ecosystem is being selectively mined, seriously threatening the associated flora. This is the only site where mining is an immediate threat to the Red Data taxa identified in this project.

Priority Area D (Haumansberg/Lemoenpoort) and Priority Area E (Nekkies) are under no immediate threat from agricultural expansion (see Fig. 5.2, 5.3 & Fig 5.4). These areas are probably fairly safe for the present. I decided, however, to leave them as priority D & E, as it may be important to conserve these areas while they are not intensively used.

The remaining Priority Areas each contain one or two threatened plant taxa. Priority H areas contain only a single Red Data species, for example *Ixia collina*, *Moraea worcesterensis* (Table 5.4). These areas are considered of conservation importance as they are the only known locations for these, predominantly "endangered", taxa.

Moddergat was giving a J rating, as one of the threatened taxa, *Nemesia pagae* occurs in the Karoo Botanic Gardens and the other has an "uncertain" rarity status. Therefore, this area does not merit a higher rating, being placed with those areas containing a single taxon not endemic to the study area.

Tweefontein (3319CB Worcester) has also been given a lower rating (K, Table 5.4). This was decided because, although the area contains 2 threatened species, viz *Ceropegia connivens* and *C. occulta*, and is under threat from agricultural expansion; the status of these threatened plant species is only "uncertain". Researchers (P. Bruyns, C. McDowell pers. comm.) believe there is a very strong chance that these species are in fact much more common and their present threatened status are a consequence of their small stature and cryptic habitat.

Although the municipality has not yet officially proclaimed the area containing the plant species, *Polhillia waltersii*, as a nature reserve, it is fairly certain that this will happen in

the near future. Thus I grouped this area at the end of the priority list (Table 5.4).

It should be mentioned again that the above priority areas cannot account for those taxa which were unmappable. It is important to assess if those "unmapped" taxa can in fact be located. Thereafter their threat status and ultimate priority for conservation can be assessed.

5.3.3 Conserving the priority areas

In considering the conservation of the above-mentioned priority areas certain questions arise, namely: how many priority areas can be realistically conserved and how should they be conserved (i.e. reserve design)? In this chapter these two questions are addressed and then various case studies in the area are presented. These studies give practical suggestions in the conservation of certain of the priority areas. In the final case study, a conservation strategy already implemented is discussed to show the rationale behind the strategy.

5.3.3.1 How many priority areas?

It is not feasible to set up conservation areas to ensure the survival of all of the threatened areas as there are economic and manpower constraints as well as a lack of popular demand. This section considers the levels of conservation effort necessary to ensure the survival of the highest possible percentage of threatened taxa. This was carried out as follows:- the cumulative number of threatened taxa in each priority area

were plotted against the Priority Area letter (Fig. 5.5). This showed that if the first five priority areas (all contain four or more threatened taxa) were conserved, 22 (36%) of the threatened taxa would be conserved in addition to those taxa already protected in existing conservation areas. If Priority Areas F & G (containing two threatened taxa) were also conserved, this would increase the overall percentage of conserved taxa in the Robertson Karoo to 57%. As the remaining priority areas contain on general only one threatened taxon, perhaps the realistic aim would be to conserve the first eight priority areas. Certain of the remaining areas, however, contain the only known location of a threatened taxon. It is important to conserve these individual species, especially those which have an "endangered" or "rare" status.

To conclude, if the first eight priority areas and the four areas (Priority Area H) containing the only location of an "endangered" or "rare" taxon were conserved, 63% of the threatened taxa would be conserved and five out of eight taxa with "endangered" status would be conserved. This is a fairly realistic starting point for conserving the Red Data taxa and their associated ecosystems in the Robertson Karoo.

5.3.3.2 Reserve design

At this stage it is important to discuss a possible strategy for the conservation of the above mentioned priority areas. The optimal design of nature reserves, which aim to conserve certain ecosystems, habitats and individual species, has been a matter

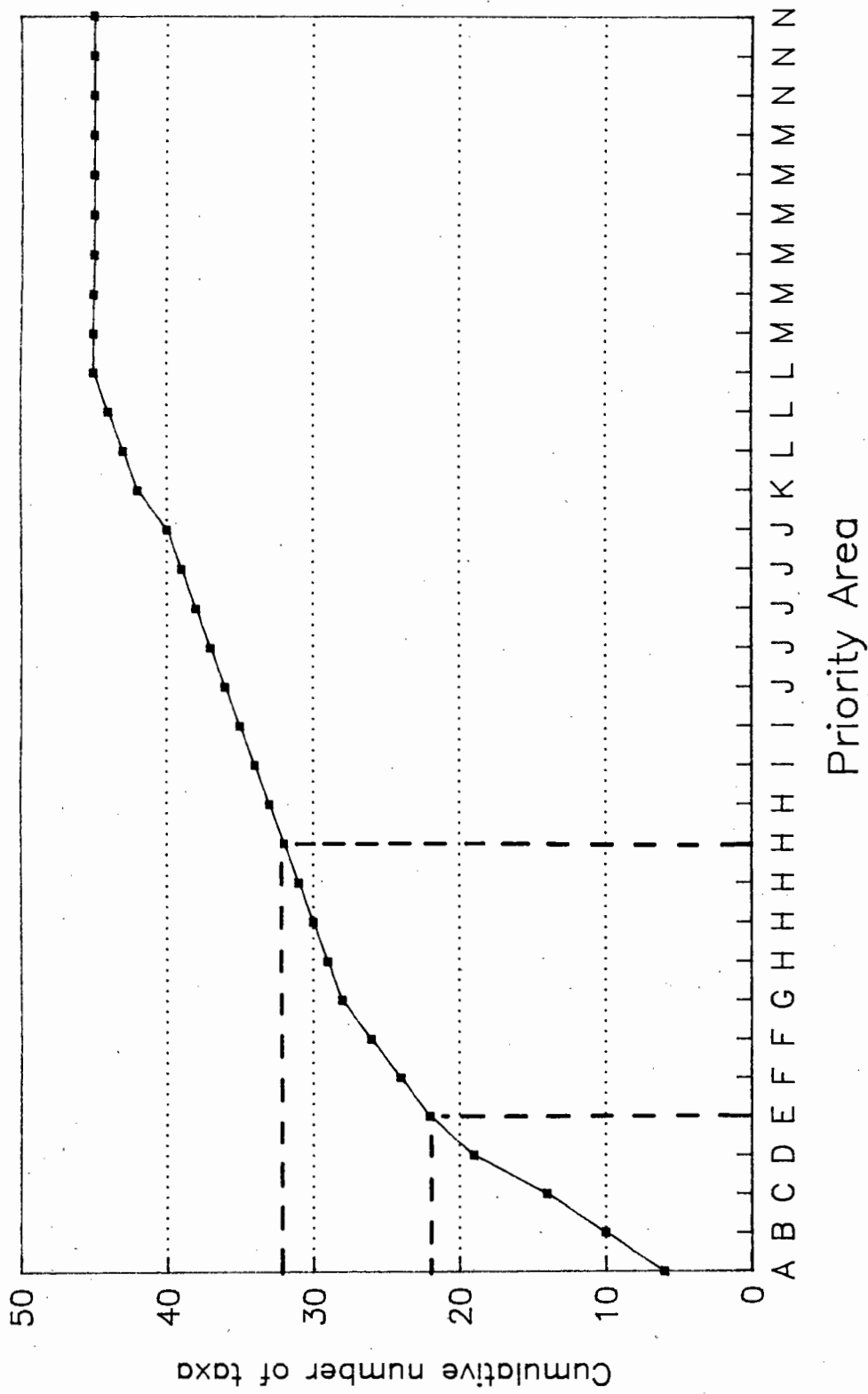


Fig. 5.5: Cumulative number of threatened taxa versus the Priority Area

of much controversy.

The Equilibrium Theory of Island Biogeography (MacArthur & Wilson 1967) has been widely applied to the question of optimal reserve size, culminating in a lively S.L.O.S.S. (single-large-or-several-small) debate (Bond 1989, Burgman *et al* 1988, Diamond 1975, Gilpin & Diamond 1980, Higgs & Usher 1980, Simberloff & Gotelli 1984, Zimmerman & Bierregaard 1986). Bond (1989), reviewing the debate in the southern Africa context, concludes that the Equilibrium Theory does have some relevance as it can predict the magnitude of the loss of species relative to the size of the habitat remnant and its isolation. More recently, the most widely used model at the population level is the Minimum Viable Population Theory (Soulé 1987). The aim is to predict the minimum number of individuals that will ensure (at an acceptable level of risk) that a population will persist in a viable state for a given time period (Gilpin & Soulé 1986).

In the Robertson Karoo, there are certain constraints in reserve design, notably the fragmentation of the natural vegetation. This rules out reserves which are large in area, thus rendering the SLOSS debate inapplicable. In addition the priority areas themselves are localized areas and relatively small in extent (generally <5km²). Thus, as this thesis is concerned primarily with the conservation of a single or few species and their associated ecosystem, the minimum viable population is, in theory at least, an effective tool in the conservation of the priority areas.

Thus, population dynamics data of the threatened plant taxa or the "key" species in the associated ecosystem, are required to ensure that the areas conserved are sufficiently large enough to contain minimum viable populations of these taxa. However, rather than wait for the necessary experimental work to be conducted, conservation plans should be implemented as soon as possible, to improve the conservation status of as many of the high priority areas as possible (see section 5.3.3.1).

Therefore, a network of reserves should be formed to conserve the priority areas. B. Bayer of the Worcester Veld Reserve (pers. comm.) suggested that areas of 5-10ha would be sufficient to conserve the clusters of threatened plant taxa, as many of these threatened plant taxa occur naturally in very localized patches (Hilton-Taylor 1989, personal observations). However, as the conservation priority areas (especially in the first 5 priority areas) identified cover on average an area of 5km² (Fig. 5.3, personal observations) the author feels that 5-10ha would be insufficient and an area near 5km² would be more realistic. In the areas containing only one threatened taxa, a smaller area could be conserved. The size of the area, as many of these localized species occur on remnant vegetation patches for example *Ixia collina* and *Ixia pumilio*, would be dictated by the extent of remnant patch on which the taxa is surviving at present. As suggested by Bayer (pers. comm.) 5-10ha would perhaps be sufficient in the above cases. The work of Brown

(1988b) supports the case for a network of small reserves. She suggested a system of numerous reserves in close proximity to one another would be appropriate for the conservation of rare and endangered Proteaceae. These reserves could be managed by a central body, e.g. Karoo Botanical Gardens. Alternatively, private landowners could be persuaded to conserve as is highlighted in the following case studies.

5.3.3.3 Case Studies

(i) Case Study 1: Brandvlei Dam Region

The vicinity of Brandvlei Dam is put forward as the area with the highest conservation priority (Table 5.4 & Fig. 5.4). Steps should be taken initially to alert landowners to the rarity of the vegetation on their properties. This area is threatened by alien infestations and potential agricultural expansion.

The only existing conservation area in the vicinity is the Quaggasberg Private Nature Reserve to the east of the Dam. This area conserves only a small number of threatened plant taxa (only positive Red Data plant collection in the reserve is that of *Gladiolus virescens* var. *roseo-venosus*, B. Bayer pers. comm.) and includes a minimal area of the apparently unique lowlying community. It is hoped that this area will be effectively conserved in the future as it is to form a part of a recreational centre (Section 5.1.1).

The area to the west and south of the Brandvlei and Kwaggaskloof

is not used intensively at present and it is likely that the Department of Prisons could be persuaded to conserve it. Apart from a new prison planned at Kweekkraal, the area is likely to remain free of related developments. Kweekkraal is the type locality for *Gladiolus virescens* var. *roseo-venosus* (rarity status: Indeterminate). The landscape consultants evaluating the development have expressed a positive concern in preserving the natural vegetation. It hoped, therefore, that the prison and associated buildings will be constructed either on previously ploughed lands or on vegetation not including the threatened wind-blown sand habitats where this "intermediate" taxa may still occur.

(ii) Case Study 2: Worcester Municipality

The Red Data taxa recorded in the Worcester municipality are under threat from urban development. Certain of these species, e.g. *Moraëa worcesterensis* may already be extinct as a result of recent urban development.

The municipality, however, does intend to set aside the area to conserve the endangered *Polhillia waltersii* (see section 5.3.2). This is a good case study example of how effective communication may help to persuade decision-makers in the local authority to conserve. Monitoring is desirable to ensure that the area is in fact adequately conserved.

(iii) Case Study 3: Areas containing a single threatened species

which is restricted to that locality, e.g. *Ixia collina*.

Various ideas introduced in the previous case studies show that an important conservation strategy is persuading private landowners or decision-makers to conserve. McDowell *et al.* (1989) note that farmers have a vital influence on the continued existence of many key ecosystems. In certain areas in the Robertson Karoo there are threatened plant taxa restricted to a single locality (Table 5.4, Priority areas H), usually to a small area on a private farm. With appropriate communication and incentives, landowners may be persuaded to conserve the habitats supporting these localized populations of threatened taxa.

(iv) Case Study 4: Vrolijkheid Nature Reserve

This case study examines the rationale for enlarging Vrolijkheid. At present plans to enlarge Vrolijkheid have been passed by the CDNEC (Q. Hahndick pers. comm.). The reserve is to be expanded to the north and north-east into the state-owned land of Elandsberg presently not utilized. The state aim is to increase the size of Vrolijkheid to support and maintain viable populations of endangered mammals. A small area of river flats may possibly be included in the extension, but apart from that, no new habitats or unique features will be acquired with the extension. The enlarging of Vrolijkheid must be encouraged as the conservation of any part of the unique Robertson Karoo is important. However, it is a serious problem that other areas of greater conservation priority, at least as far as threatened plants are concerned, have apparently been ignored.

5.4 CONCLUSIONS

The majority of the 61 threatened plant taxa in the Robertson Karoo occur to the west of the area in an ecotone from Karoo to Fynbos. In addition a large percentage of the taxa (50%) appear to be confined to areas of high agricultural threat. Alien infestations (along the banks of the Breede River and in the vicinity of Brandvlei Dam), mining and urbanization (in the vicinity of Worcester) threaten 25% of Red Data taxa.

Conservation strategies for homogenous stands of Karroid Broken Veld and for mammals appear to have been over-emphasized, e.g. Vrolijkheid Nature Reserve, whereas incidence of threatened plants/vegetation communities have been, for the most part, ignored. This is evidenced by the fact that 89% of the threatened plant taxa do not occur in the existing reserves. Conserving the first five priority areas would protect 36% of the threatened plant taxa, in addition to those taxa already conserved in the existing reserves. If an additional three priority areas (Priority Area F & H) with the four areas (Priority Area H) containing an "endangered" or "rare" taxon were conserved, this would improve the conservation status of the Robertson Karoo by conserving 63% of the 61 threatened plant taxa. This is a realistic starting point to saving the threatened taxa and their associated endangered habitats.

An important strategy in conserving the above priority areas is the involvement of private landowners and decision-makers in

firstly, alerting them to the rarity of the vegetation and
secondly, persuading them to conserve.

APPENDIX 1

Threatened plant taxa of the Robertson Karoo

1 *Ophioglossum nudicaule* L.F. Rare

Geophytic fern which grows under shrubs in transitional zones between renosterveld and karroid broken veld (CH). This species appears to be widespread, however J. Vlok advised that it should be placed on the Red data list (C. Hilton-Taylor pers. comm.).

2 *Haemanthus sanguineus* Jacq. (pink) Rare

H. sanguineus is a common species; however the variety with pink flowers is endemic to Worcester area (P. Perry pers. comm.).

3 *Nerine* cf. *pubida* Hooker f. (*Nerine* sp. nov.) Uncertain

Although the identification of this species is uncertain, P. Perry (pers. comm.) regards it as "rare".

5 *Haworthia marginata* (Lam.) Stearn Endangered

This South Coast Renosterveld species has been both severely overcollected, as well as eradicated by agricultural expansion and is now confined largely to isolated remnants mainly on rocky hills (Bayer 1982).

6 *Haworthia mutica* Haw. Vulnerable

This species is known only from 2 localities, south of Swellendam and Drew, which both occur within relatively intensively farmed areas. It survives today on rocky shale ridges (Bayer 1982).

7 *Haworthia poelnitziana* Uitew. Endangered

This species grows on old river gravels (Bayer 1982).

8 *Haworthia pubescens* Bayer Vulnerable

The distribution of this species is extremely limited, occurring on only low quartzitic ridges (Bayer 1982).

12 *Lachenalia moniliformis* W.F. Barker Rare

At present known only from its type locality in the Worcester District (Duncan 1988).

13 *Lachenalia physocaulos* W. F. Baker Rare

Occurs in the Robertson and Swellendam districts in sandy ground (Duncan 1988).

14 *Neopateronia uitenhagensis* Schonl. Rare

The habitat of this species is very localized. At Buitenstekloof it occurs on a dolomite ridge (B. Bayer pers. comm.).

16 *Geissorhiza geminata* E. Meyer ex Baker Uncertain

G. geminata is a semi-aquatic species, typically found in seasonally marshy areas. It occurs in both the Worcester and Ceres districts and north into the Cold Bokkeveld (Goldblatt 1985). The associated habitat of this species, especially in the Worcester area, is threatened by agricultural expansion and

alien infestations.

17 *Gladiolus virescens* Thunb. var. *roseo-venosus* Lewis

Indeterminate

This taxa, which is endemic to the Worcester area, occurs on sandy or clay flats (Bond & Goldblatt 1984).

18 *Ixia campanulata* Houtt. Indeterminate

This species inhabits sandy lower slopes from Tulbagh to Worcester (Bond & Goldblatt 1984).

19 *Ixia collina* Goldbl. & Snijman Rare

This species is endemic to the Worcester area where it grows on moister south facing slopes of Karroid hills in the Breede River valley (Goldblatt & Snijman 1984).

20 *Ixia pumilio* Goldbl. & Snijman Rare

As far as it is known, this species is restricted to the Reiers Rus farm, where it grows in deep alluvial sand along the Breede River (Goldblatt & Snijman 1984).

21 *Ixia vanzylliae* L. Bolus Rare

Although this species has been collected from 3 localities, only one of them is known. It grows mainly on clay flats (C. Hilton-Taylor pers. comm.).

22 *Ixia* sp. nov. Uncertain

This species was collected in 1962 by F.J. Stayner (manuscript name = *mostertii* De Vos n. sp., National Botanic Gardens 86.906). As there are no additional records, this species is endangered or perhaps already extinct (C. Hilton-Taylor pers. comm.).

23 *Lapeirousia plicata* (Jacq.) Diels subsp. *effurcata*
(Lewis) Goldbl. Uncertain

This species occurs on dry flats in the Little Karoo and the Worcester-Robertson area. It has not been frequently collected but this may be a result of its small stature rather than its rarity (Goldblatt 1972).

24 *Moraea worcesterensis* Goldbl. Endangered

This species, which occurs on rocky flats, may be extinct at the locality West of Worcester (B. Bayer, P. Perry & J. Forrester pers. comm.).

26 *Ceropegia connivens* R.A. Dyer Uncertain

This species appears to be restricted to the grid reference 3319 (Worcester, D.A. Dyer 1979).

27 *Ceropegia occulta* R. A. Dyer Rare

Dyer (1980) noted that this species had only been found in the vicinity of Tweefontein. However, C. McDowell (pers. comm.) found it occurring at Buitenstekloof, Robertson. It occurs under karroid shrublets (Dyer 1983).

The above *Ceropegia* spp are small in stature and hence difficult to find resulting in their distribution perhaps to be a function of under-collection (C. McDowell pers. comm.).

29 *Stapelia scitula* Leach. Rare

This species occurs on localized dolomite outcrops (P. Bruyns pers. comm.).

30 *Stapeliopsis breviloba* (R.A. Dyer) Bruyns Uncertain

It inhabits the karroid areas of Worcester and Robertson (Bond & Goldblatt 1984) where it appears to be endemic, although it may occur as far E as Swellendam. The rarity status of this species is difficult to gauge, as it is difficult to find (P. Bruyns pers. comm.).

32 *Senecio rehmannii* Bolus Uncertain

Although little is known about this species, its riverine habitat (Bond & Goldblatt 1984) is threatened by alien infestations and agricultural expansion.

34 *Crassula* sp. nov. Uncertain

This species appears to be a fairly common Worcester-Robertson endemic (P. Bruyns pers. comm.).

35 *Grisebachia rigida* N.E. Br. Vulnerable

This species which is endemic to Worcester area grows on sandy flats (Bond & Goldblatt 1984, Hall et al. 1980).

36 *Aspalathus burchelliana* Benth. Vulnerable

This species is probably restricted to lowland clayey hills in the Swellendam and Robertson Divisions (renosterveld-fynbos transition) and hence is threatened by agricultural expansion (Dahlgren 1988).

37 *Aspalathus macrocarpa* Ecklon & Zeyher Uncertain

This species has been collected only from 2 localities, where it grows in slightly clayey soil on steep fynbos slopes (Dahlgren 1988).

38 *Polhillia waltersii* (Stirton) Stirton ined. Vulnerable

This species has only been collected within the Worcester municipality. It is hoped that it will be conserved in a future municipal nature reserve.

40, 41, 42 & 43 *Drosanthemum* sp.

Drosanthemum has not as yet been revised and little is known about this genus. The above species were mentioned by researchers in the area (B. Bayer, P. Perry pers. comm.), as being threatened although their exact IUCN status is unknown (E. van Jaarsveld pers. comm.).

44 *Gibbaeum esterhuyseniae* L. Bolus Extinct?

This species which appears to be extinct, occurs on white

quartzite patches in a triangular area bounded by MacGregor, Bonnievale and Stormsvlei (Glen 1974).

47 *Lampranthus vanzijliae* (L. Bolus) N.E. Br. Endangered
Endemic to the area, this endangered species occurs on sandy ground. It may even be extinct (B. Bayer pers. comm.). There is some confusion as Bond & Goldblatt (1984) gave a wide distribution for this species ("Clanwilliam to Darling, Worcester, Caledon").

50 *Oxalis dregei* Sonder Rare
This species occurs in marshes, streams or seeps (Bond & Goldblatt 1984).

51 *Oxalis natans* L.f. Rare
This Aquatic geophyte occurs in stagnant pools, Piketberg, Peninsula, Worcester (Bond & Goldblatt 1984).

53 *Leucadendron chamelaea* (Lam.) I.J. Williams Endangered
This species, which occurs on flat alluvial ground in the Ceres and Worcester districts (Bond & Goldblatt 1984) in renosterveld, is severely threatened by agricultural expansion.

54 *Leucadendron flexuosum* I.J. Williams Endangered
This species occurred in Hartebeesrivier Nature Reserve, which has been deproclaimed for the new national road bypass. However, steps to proclaim another tortoise reserve in the vicinity might result in the conservation of this species. It is common locally on alluvial flats west of Worcester (E. van Jaarsveld pers. comm.).

56 *Protea restionifolia* (Salisb. ex J. Knight) Rycr. Vulnerable
Occurs on dry mountain renosterveld (especially common on ecotones between fynbos and karrooid shrub), Caledon and Worcester. Although it is locally common this species is poorly known (J. Rourke pers. comm.).

58 *Agathosma stipitata* Pill. Uncertain
This species has a limited distribution and occurs on lower north facing slopes (c1000-3000ft), Riversonderend Mountains, Brandvlei Berg (A. Bean pers. comm.).

59 *Euchaetis pungens* (Bartling & Wendl.) I.J. Williams
Uncertain
This species grows on pure wind blown sandy ground at low altitudes (c 800ft) and thus are likely to be threatened (A. Bean pers. comm.).

51 *Sutera cephalotes* Kuntze Uncertain
The identification of this species collected from the locality, Brandvlei hills, may be incorrect (D. Snijman pers. comm.). This species has not been revised and little is known about it.

** It is worth briefly mentioning a threatened plant taxa which

occur just outside the study area and thus was omitted from this project: *Erepsia villiersii* occurs on the Rooihogte Pass (grid reference = 3319CD). This species is apparently limited to one locality and may even be extinct (C. Hilton-Taylor pers. comm.). It is vitally important to ascertain if this species still exists.

CHAPTER 6: CONCLUSIONS

6.1 SPECIFIC CONCLUSIONS

To assess the success of this thesis in achieving its aim, it is necessary to review the conclusions:

1) The Robertson Karoo environment has had a long history (20 000 years) of human impact. There are no reliable records of the vegetation before the 18th century.

2) Evidence indicates that the vegetation of the early colonial period was dominated, as it is today, by karroid chamaephytes with a low percentage of grass cover. There is no evidence as to whether the species composition has changed to any great extent since the time of arrival of the European settlers. Contemporary studies and personal observations do, however, show extensive soil erosion with much of the topsoil having been lost. When and how these changes, and the possible undocumented changes in the environment before the 18th century, took place cannot be established. The anthropogenic impacts of both the Khoi and the European settlers appear to have played a significant role in vegetation change. Climate undoubtedly also played a role.

3) In early colonial times, the karoo vegetation of the Middle Breede River Valley was surrounded by less xeric grassy vegetation on the foothills of the mountains and in the plains to the east of the study area. In these regions there has been a shift in dominance away from grassland to renosterbos (*Elytropappus rhinocerotis*) scrubland. It appears that this change in the vegetation, as has been documented in the literature (Cowling *et al.* 1986), is the result of more intensive and sustained grazing by domestic stock, especially

during post-fire periods.

4) Until the 18th the Breede River itself was flanked by a wide, grassy floodplain. This has been greatly reduced today through irrigation practices and the establishment of dams which now control the river's flood waters.

5) The greatest impact of the European settlers has been the reduction in the extent of the remaining vegetation as a result of agricultural expansion and urbanization.

6) Between 1942 and 1987 the natural vegetation of the Robertson Karoo decreased on average by 0.7% per annum of the total study area. By 1987, 34% of the natural vegetation in the region had been cleared.

7) The major threat to the natural vegetation of the Robertson Karoo is agricultural expansion. This factor is often irreversible.

8) The major agricultural product of the Worcester-Robertson valley is wine grapes. This crop and the majority of other products produced in the Robertson Karoo are grown under irrigation owing to the arid nature of the region. Thus agricultural expansion is limited by the availability of water for irrigation.

9) Livestock farming in the Worcester-Robertson area is a minor source of income (between 6-7% of the total annual income). In addition, the majority of the livestock are grazed on planted pastures and/or given additional food. The natural vegetation is under-utilized. When livestock are grazed on the natural vegetation, farmers are usually unconcerned with the carrying

capacity of the vegetation or veld improvement programmes.

10) Alien infestations are severe only along the rivers and in the vicinity of Brandvlei Dam.

11) Veld burning practices are not an important feature in most of the Robertson Karoo.

12) Urbanization is an important localized threat. Results show that the extent of the largest town, Worcester, has doubled in size since 1954. Another threat is mining and there are already two extensive quarries in the valley.

13) The following areas are immediately threatened, namely:

a) The low-lying vegetation surrounding Worcester.

b) The remaining areas of high agricultural threat.

c) Low-lying river flats threatened by alien vegetation.

d) Communities growing on a substrate, e.g. dolomite, which has the economic potential to be mined.

14) Agricultural threat indices calculated in 275 units of the study area correlate significantly ($r_s(2) = 0.6$; $P < 0.001$) with the pattern of previous clearance of the natural vegetation, indicating that these indices are of value in predicting the likelihood of future agricultural expansion. However, it appears that other factors also come into play when assessing the potential agricultural threat of an area, the most important being distance from the rivers, a source of irrigation water.

15) No absolute prediction for the agricultural expansion in a particular area is possible, because the human factor is indeterminable and may override all other parameters.

16) There are 61 threatened plant taxa in the study area and 43

taxa which are endemic to the valley. More than 50% of the threatened taxa are located west of the longitude line 19°30' E in a community which is transitional from Karoo through Renosterveld to Fynbos. In addition it was found that only 25% of the taxa occur in true Karroid Broken Veld.

17) At present 2.39% of the Robertson Karoo (3.62% of the remaining vegetation) is conserved, but most of the unique and threatened habitats do not occur in these conserved areas. In fact, only 11.5% of the threatened plant species are conserved in existing reserves. In the past, conservation strategies for homogeneous stands of Karroid Broken Veld and for mammals have been over-emphasized, as is the case in Vrolijkheid Nature Reserve, whereas the incidence of threatened plant taxa and vegetation communities have been ignored.

18) Urgent attention is required to save many of the threatened taxa and endangered habitats before they disappear. It would be realistic aim to conserve at least the first five priority areas, i.e. Brandvlei Dam Region, the Breede River floodplain, Buitenstekloof, Haumansberg and Nekkie hills (see Fig. 5.3). This would conserve 36% (in addition to the 11.5% already conserved in existing reserves) of the threatened plant taxa and their associated ecosystems. If an additional three priority areas (Priority Area F & H) with the four areas (Priority Area H) containing the only location of an "endangered" or "rare" taxon were conserved, this would increase the over all percentage of threatened taxa, conserved in the Robertson Karoo, to 63% (Fig. 5.5).

18) Landowners could play an vital role in conserving the priority areas. Whilst it has been acknowledged that large-scale agricultural expansion is unlikely in the near future (Chapter 3), it is time to initiate urgent steps to conserve those priority areas threatened by agricultural expansion. Reluctance to take action now may lead to failure in the future, as landowners are more willing to support conservation efforts whilst pressure on these areas is low than when the demand for them increases. Once established, conservation areas are, hopefully, less easily deproclaimed. This also applies to areas, e.g. the Nekkie Hills, which have at present a low potential utilization.

19) It is suggested that a network of reserves should be formed to conserve the priority areas. It is likely that 5km² would be sufficient to conserve the larger priority areas (i.e. Priority Areas A-F). The remaining localized priority areas could, perhaps, be conserved in smaller areas such as 0.05-0.1km², a figure suggested by B. Bayer (pers. comm.).

6.2 CONCLUDING REMARKS

The Robertson Karoo is an interesting region botanically, agriculturally and industrially. Much of the vegetation is ecotonal, the valley supports varied agricultural activities, and also has a high potential for industrial expansion in the long term.

Recent environmental transformations over the last 100 years, especially agricultural expansions, have had a great impact on

the natural vegetation of the Robertson Karoo. This has been highlighted by the decrease in the extent of natural vegetation coupled with the change in land use patterns in the seven representative areas. Unfortunately, a downfall of the study here, perhaps, was the subjective way in which the areas were chosen. A statistical approach would have randomized the choice of the subjects, enabling the data to be statistically analysed. This would have lent greater weight to predicting future agricultural trends.

The project does, however, provide a comparative prediction of the differing likelihoods of agricultural clearance for various physiographic units covering the entire study area. The resultant map (Fig. 4.6) is of considerable use to conservation planners. This complements the information on the future transformations gained from Chapter 3. By some standards one short-coming of the map (Fig. 5.6) is that it is restricted to a small scale (1:250 000). However, as the Robertson Karoo covers a considerable area, 2332km², it would be unrealistic, given the standard of available data, to produce a larger scale map (i.e. the area covers nine 1:50 000 topographic maps). The inclusion of greater detail would provide for a less holistic interpretation of the whole area for the conservation planner.

Ultimately the project has identified threatened areas of conservation value which should be urgently protected to avoid species extinction and the disappearance of associated rare

and/or threatened habitats. The most pressing future research is to assess in greater detail the proposed conservation areas and to act accordingly. The value of conserving these localized habitats could be questioned within the larger context of the ozone depletion and the possible global warming that is at present being experienced. The effects of future climatic changes, however, cannot realistically be quantified. Thus whether the many localized communities characterizing the Robertson Karoo study area will survive them, cannot be accurately determined. It must, therefore, still remain an issue of prime importance to take steps to ensure their conservation now.

This project has also collated a huge data base on the Robertson Karoo environment. This is in the form of maps depicting the geology, soil, precipitation, slope gradient, areas of agricultural threat, location of threatened plant taxa and areas of high priority conservation. It is hoped that these maps will in the future be transferred onto a Geographic Information System (GIS). The data on such a system can be retrieved at will, transformed, reassessed and displayed. This will allow planners and decision-makers to explore a range of possible scenarios and to obtain an idea of the consequences of a particular event. This will be a useful tool in aiding the conservation and management in the Robertson Karoo.

This project illustrates the vital importance of the human factor, firstly as the initiator of the threats to the natural

vegetation and secondly in its role in protecting and conserving the natural vegetation. The dominant vegetation (Karroid Broken Veld) of the Robertson Karoo, especially since a large proportion of it is conserved in Vrolijkheid Nature Reserve, is not in danger of disappearing in the near future. In the past conservation strategies have over-emphasized the conservation of large patches of homogenous vegetation stands and the conservation of mammals. The specialized threatened habitats types within the Broken Karroid Veld, e.g. the dolomite and quartzite outcrops, the ecotonal and the sandy low-lying habitats especially in the vicinity of Brandvlei Dam have been completely ignored in practice by conservation decision-makers. Attention should be immediately focused on these localized areas, most of which contain threatened plants and unique communities in danger of extinction owing to oversights in previous conservation planning.

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