



A guide to the literature on research in the grassland biome of South Africa

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A Report of the Committee for Terrestrial Ecosystems
National Programme for Environmental Sciences

SOUTH AFRICAN NATIONAL SCIENTIFIC PROGRAMMES REPORT NO

96

DECEMBER 1984

(ii)

Issued by
Foundation for Research Development
Council for Scientific and Industrial Research
P O Box 395
PRETORIA
0001
from whom copies of reports in this series are available on request.

Printed in 1984 in the Republic of South Africa

ISBN 0 7988 3258 4

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ABSTRACT

Research into the management of grassland communities in South Africa spans a period of more than 50 years. The work has covered a wide range of topics relating to the form and function of grassland communities, and has had as its main objective the development of an understanding of how these communities can best be managed to ensure their sustained productivity, or indeed to increase their productivity. This publication serves to highlight the main work which has been undertaken in this biome, with the primary intention of providing a ready access to the South African literature on research in the grassland biome.

OPSOMMING

Navorsing oor die bestuur van grasveldgemeenskappe in Suid-Afrika strek oor 'n periode van meer as 50 jaar. Die werk het 'n wye reeks onderwerpe in verband met die aard en funksie van grasveldgemeenskappe gedek en het as hoofdoelstelling gehad die uitbouing van die begrip van hoe die gemeenskappe ten beste bestuur kan word om hul volgehoue produktiwiteit te verseker, of om inderdaad hul produktiwiteit te verhoog. Hierdie publikasie lig die hoogtepunte van die werksaamhede binne hierdie bioom toe. Die primêre oogmerk van die publikasie is om 'n vrye toegang tot Suid-Afrikaanse literatuur oor navorsing in die grasveldbioom te voorsien.

PREFACE

Grassland research has featured prominently in the field of ecological endeavour in South Africa. Detailed studies of the interactions between fire, livestock and forage production have been an important aspect of research over more than sixty years. Despite the wide range of research activities generated during this period, much of the work has been directed to isolated topics, often only remotely integrated with the findings or efforts of other studies. In order to stimulate greater coherence in grassland research projects in South Africa, and to bring greater focus on issues of national concern, the Grassland Biome Project was launched in 1978 within the National Programme for Environmental Sciences. The National Programme is a cooperative undertaking of scientists and scientific institutions involved in research on problems of the environment. Funds for the Grassland Biome Project are drawn from the budgets of participating organizations, and from a central fund provided by the Department of Environmental Affairs and administered by the National Committee for Environmental Sciences.

This report reviews in as succinct a form as possible, the published material on various features of grassland ecology and management in South Africa. It is structured following the major themes and key questions being addressed within the Grassland Biome Project (Mentis and Huntley 1982) and provides a comprehensive guide to the South African literature on the subject.

The bibliography has been compiled from contributions by participants in the Grassland Biome Project, in particular Dr J C Scheepers (Botanical Research Institute and Dr M T Mentis (University of Natal) who are thanked for the major contributions they have made to its preparation.

ACKNOWLEDGEMENTS

Thanks are extended to Dr M T Mentis for assisting in the literature search and to Mr B J Huntley for his valuable advice during the preparation of the document. Dr J C Scheepers and his staff provided valuable assistance in collating the reference list, which was prepared in its final form by Mrs M Orton. Thanks are also due to Mrs M L Goddard for the preparation of the text of the document.

CONTENTS

	Page
ABSTRACT / OPSOMMING	(iii)
PREFACE	(iv)
ACKNOWLEDGEMENTS	(iv)
1. INTRODUCTION	1
2. DEFINITION AND DESCRIPTION OF THE GRASSLAND BIOME	3
2.1 ORIGIN, LOCATION AND EXTENT OF GRASSLANDS	3
2.2 THE MAIN VEGETATION TYPES WITHIN THE GRASSLAND BIOME - FLORISTICS AND PHYSIOGNOMY	3
2.3 RELATIONSHIP BETWEEN GRASSLAND TYPES AND SOIL TYPES	6
2.4 RELATION BETWEEN GRASSLAND TYPE AND CLIMATE	6
2.5 FAUNA AND WILDLIFE RESOURCES	7
2.6 RARE AND ENDANGERED SPECIES	8
3. ECOSYSTEM PROCESSES WITHIN THE GRASSLAND BIOME	9
3.1 SPATIAL AND TEMPORAL VARIATIONS IN THE DRIVING VARIABLES	9
3.2 EFFECT OF DRIVING VARIABLES ON PERFORMANCE OF INDIVIDUAL PLANTS AND SWARDS	10
3.3 EFFECT OF DRIVING VARIABLES ON THE RESPONSE OF COMMUNITIES	13
3.4 INFLUENCE OF DEFOLIATION ON THE RESPONSE OF INDIVIDUAL PLANTS TO DRIVING VARIABLES	13
3.5 INFLUENCE OF DEFOLIATION ON THE RESPONSE OF COMMUNITIES TO THE DRIVING VARIABLES	14
3.6 ROLE OF FIRE, HERBIVORY AND DECOMPOSITION ON SOIL WATER AND NUTRIENTS	15
3.7 INFLUENCE OF ABIOTIC AND BIOTIC FACTORS ON RATES AND INTENSITIES OF FIRE, HERBIVORY AND DECOMPOSITION	15
3.8 INTERRELATIONSHIP BETWEEN ANIMALS AND PLANTS	15

4. GRASSLAND DYNAMICS	17
4.1 CHANGES TAKING PLACE BETWEEN GRASSLAND AND OTHER BIOMES	17
4.2 CHANGES TAKING PLACE WITHIN GRASSLANDS	17
4.3 RATE AT WHICH CHANGES ARE TAKING PLACE	19
4.4 MAJOR CAUSES OF CHANGE	20
5. MANAGEMENT AND UTILIZATION OF THE GRASSLAND BIOME	22
5.1 DESCRIPTION OF RESOURCES IN RELATION TO LAND-USE POTENTIAL	22
5.2 PROJECTIONS OF FUTURE LAND-USE PRACTICES	22
5.3 LIMITATIONS TO LAND-USE WHICH EXIST OR ARE LIKELY TO ARISE	23
5.4 OPTIONS IN ALLOCATING RESOURCES TO IMPROVED LAND-USE AND GRASSLAND RESPONSE TO THESE OPTIONS	25
- Objectives of management	25
- Management options	25
- Grassland management	26
6. REFERENCES	33
7. RECENT TITLES IN THIS SERIES	76

1. INTRODUCTION

Research work in the South African grassland biome arose largely in response to a report of the Drought Investigation Commission published in 1923. This Commission had been appointed in 1920 to investigate and report on certain matters connected with periodic droughts in South Africa, with the objective of identifying those factors which contributed to what was believed to be an increasing frequency and intensity of droughts. The Commission concluded that a number of factors appeared to contribute to the increase in drought incidence, but that in essence the drought problem was being aggravated by a man-induced deterioration of the vegetal cover, leading in turn to an increased runoff and soil loss, and a reduced capacity of the soil to hold up and absorb water during any rainfall event. The Commission recognized, however, that there was a general lack of information on appropriate management of South African veld, and recommended that the Government of the day promote research into the management of various types of veld.

The recommendations of the Drought Investigation Commission with respect to the promotion of research into veld management was perhaps largely instrumental in the acquisition, by the Department of Agriculture, of a number of research farms during the 1930's. Research into veld management largely dates from this time, although a number of vegetation surveys had preceded this, and provided useful background information for decisions on the siting of the research units.

Within the grassland biome, research units were established at Athole, Rust der Winter, Dohne, Tabamhlope and Estcourt. These were later added to when research stations were developed at Kokstad and Dundee, and to these may be added the field research units based at the Cedara, Potchefstroom and Glen Colleges of Agriculture, and the Universities of Pretoria, the Witwatersrand, Orange Free State and Natal.

In addition, however, to the research undertaken by the Department of Agriculture and the Universities during the last 50 or so years a substantial contribution has been made by other organizations. In particular, the Department of Forestry, the National and Provincial Parks Boards, and the CSIR have stimulated and supported veld work. The combined research output of these organizations has indeed been substantial. However, since a number of independent bodies have played a part in this research effort, it is not surprising that research has lacked a coordinated approach. No specific umbrella goals appear to have been set outside the general need to provide information which would lead to a better understanding of the structure and function of grassland communities and, in particular, their reaction to the manner in which they are treated. Such lack of coordination applies to both the geographical distribution of the research and to the fields which have been researched. Some fields of research have received extensive coverage, while others have received scant attention. Moreover, even in those fields which have received a substantial amount of research attention, different researchers or research groups have often worked independently of each other, so that a comprehensive picture has seldom emerged.

To provide an overall review of the research findings which have emerged from 50 or so years of work in the grassland biome would be a mammoth task. Indeed, this document makes no attempt to do this. The objective here has been to provide no more than a guide to the research undertaken within the biome and to provide a reasonably complete bibliography of research publications in this biome. The intention has been to provide prospective researchers with an outline of the types of work which have been undertaken in different geographical areas, to direct researchers to the appropriate literature in any field or geographical area, and to highlight the deficiencies of research information which currently exist within the grassland biome. In providing this service, it is hoped that the document will contribute to research planning and in so doing, provide for better coordination between the work which has already been done and that which still needs to be done.

2. DEFINITION AND DESCRIPTION OF THE GRASSLAND BIOME

2.1 ORIGIN, LOCATION AND EXTENT OF GRASSLANDS

The first notable account of the major types of vegetation in South Africa was published by Bews in 1916 (Bews, 1916a), to be followed two years later by a second publication on the grasses and grasslands of South Africa (Bews, 1918a). Almost two decades later, Pole Evans (1936) published a generalized vegetation map of South Africa, in which he defined geographically the limits of each of the vegetation types. Similar vegetation maps were later produced by Adamson (1938) and Pentz (1949), each using somewhat different criteria to define the vegetation units. Nonetheless, there was a great deal of uniformity in these three classifications, which were all relatively broadly based.

The next major advance, and one which remains in general use today, was the classification of the veld types produced by Acocks in 1953, a revised edition of which was produced in 1975. Here South Africa was divided into 70 major units which included 13 'pure' grassland types which were considered to be climatic climax grasslands and a further eight false grassland types, considered to be derived (largely fire-climax) types. Additional essentially grassveld types were also identified and mapped as Coastal tropical forest types (six), Inland tropical forest types (two) and Temperate and transitional forest and scrub types (two). In all, therefore, Acocks (1975) defined 31 units within the grassland biome. In this publication he also discussed evolutionary aspects of South African vegetation and changes in vegetation during the past three centuries. This publication remains the most widely used and useful of the classifications of South African vegetation, as for example by Tainton (1981a) in his text on the management of veld and pastures in South Africa.

More recent classifications include those of Phillips (1971) and a series of descriptions in 'Biogeography and ecology of Southern Africa', edited by Werger and published in 1978. Included here are chapters on the Biogeographical division of southern Africa (Werger, 1978), the Sudano-Zambezian region (Werger and Coetzee, 1978), the Afro-alpine region (Killick, 1978) and the Afro montane region (White, 1978). Edwards (1976) also described the floral resources of southern Africa.

Further publications of relevance to the description of the vegetation of the grassland biome in South Africa include those on plant forms and their evolution in South Africa (Bews, 1925) and on the evolution of South African veld types (Anon, 1970).

2.2 THE MAIN VEGETATION TYPES WITHIN THE GRASSLAND BIOME FLORISTICS AND PHYSIOGNOMY

Detailed studies of individual communities and vegetation types have been undertaken throughout the grassland region, and such studies have, to a

large extent, been grouped for convenience around major research centres and only occasionally in areas which for some or other reason have been identified as being especially important or perhaps ecologically particularly interesting. In a number of instances, however, the selection of the site studies appears to have been based on nothing more than its convenient location. No real attempt has apparently been made to investigate units of vegetation identified in previous classifications, and therefore to refine such classifications. In particular, the location of study sites with a view to maximising the extrapolation and applicability of research findings has seldom been taken into account. We are therefore left with an incomplete series of studies of isolated areas, often presented in such a way that they cannot readily be used to improve on our specialized knowledge of the major grassland units. Also, it should be noted that many of these studies have been concentrated on the associated plants of the grassland communities rather than on the grasslands themselves, and while of interest, they ignore the dominant life form in the general area studied.

By far the greater proportion of the studies undertaken on individual communities of specific geographical regions within the grassland biome have been undertaken in Natal. These include the broader work on, for example, the vegetation of Natal (Bews, 1912), the growth forms of Natal plants (Bews, 1916b), researches on the vegetation of Natal (Bews, 1931), an agroecological survey of Natal and the accompanying map (Pentz, 1949), notes on the vegetation of Natal (Bayer, 1953) and the flora of Natal (Ross, 1972) and its analysis (Ross, 1973). Analyses of essentially coastal vegetation types include those of Bews (1920), Forbes (1921), Campbell (1966; 1969), Breen (1971) and Moll and White (1978). Bayer (1938) provided an account of the plant ecology of the coastal belt and midlands of Zululand, and Aitken and Gale (1921) of a botanical survey of north-eastern Zululand.

The Tugela region of Natal has received considerable attention because of its predicted future as an industrial growth point. Publications concerned with the vegetation of this area include those of Woods and Moll (1967), Edwards (1967) and Phillips (1973). Other surveys in the Natal Midlands include those of Bews (1913), for the Pietermaritzburg area in particular, West (1951) for the Weenen county, Killick (1958) and Wells (1959) for the Table Mountain and Nagel Dam area, Moll (1968a) for the Upper Mgeni catchment, Moll (1976) for the catchments of the Mvoti, Mgeni and Lovu Rivers, and Moll (1968c; 1978) for the Kranzkloof. Downing (1966; 1968; 1970), Scotney (1970) and Turner (1970) have published accounts of vleiv vegetation in Natal and Moll (1968b) of the aquatic vegetation of Midmar Dam.

The montane vegetation of Natal has been described by Galpin (1908), Bews (1917) and Killick (1963). Killick (1963) in particular, discussed the montane, sub-alpine and alpine vegetation in terms of altitudinal zonation, and Westfall et al (1983) have described the vegetation of protected areas on the Thabamhlope plateau, which gives a useful insight into the ecology and dynamics of the Highland Sourveld. A general key to the common veld grasses of Natal and a description of their distribution and ecology has been provided by Tainton et al (1976).

In the Orange Free State, Potts and Tidmarsh (1937) published the results of a vegetation survey in the Bloemfontein area, and Mostert (1957) of

parts of the Bloemfontein and Brandfort districts. Roberts (1963a; 1969b) surveyed the vegetation of two of the game parks (Willem Pretorius and Golden Gate Highlands National Park), Werger (1973a) a Game farm, and Scheepers (1969) undertook a preliminary association analysis of the Kroonstad area and studied the ecology of the Kroonstad and Bethlehem areas (Scheepers, 1975). Mostert (1967) discussed generally the veld types and the problems endangering the potential of the veld in the Orange Free State region as a whole, while Roberts (1973) described the common grasses of this region. Jarman and Bosch (1973), using satellite imagery, attempted to assess the extent of encroachment by Karoo vegetation into the Grassland biome area.

In the Transvaal, Phillips (1929) provided an early sketch of the flora of the environs of Pretoria and Louw (1951) provided an account of the vegetation of the Potchefstroom area and a checklist of the vegetation of the dolomitic region. Louw (1970) and Gilliland (1955) discussed the phenology of monocotyledons found in the veld around Johannesburg. The vegetation of nature reserves has been described by van Zyl (1965) for the S A Lombard reserve and Bredenkamp (1975) and Bredenkamp and Theron (1976) for the Suikerbosrand. More generally, Glover (1937) discussed the ecology of highveld flora, Grunow and Morris (1969) assessed the ecological status of plant species in three different veld types, and Roux (1969) in his book 'Grass - a story of Frankenwald' describes much of the early research undertaken on the grassland at the Frankenwald Research Station. Morris (1973; 1976) has investigated the ecology of the vegetation of the Lichtenburg area and has also examined the ecological interrelationships of some of the important component species of the area (Morris and Guillerm, 1974).

Finally, in the Cape Province, Story (1952) produced an extremely comprehensive and valuable report on the vegetation of the Keiskammahoek district. Werger (1973b) described the vegetation of the Upper Orange River Valley, and Fourie and Roberts (1976) of three veld types in the Vryburg districts. Roberts and Fourie (1975) have described the common grasses of the northern Cape, and discussed their distribution and ecology.

In considering these publications, it becomes clear that their objectives vary widely. With few exceptions there has been little or no coordination between different workers, and as mentioned previously, there has been no consolidated attempt to refine the more general classifications of the grassland biome presented by Pole Evans (1936), Adamson (1938), Pentz (1949) and Acocks (1975). Mindful of the general lack of coordination and compatibility between the approaches, methods and findings of the various workers mentioned above, the Botanical Research Institute has fostered the approach and methodology of the Zurich-Montpellier School of Phytosociology and urged that they be widely used in order to standardize the concepts and nomenclature of descriptive vegetation ecology. The adoption of standardized approaches, methods and terminology is not intended to encourage their exclusive use but that they be used complementarily with other descriptive methods such as veld condition and trend assessments. This standardization is intended to effect the necessary comparability and compatibility of findings to provide the basis of more detailed classifications of vegetation than that of Acocks' veld types (1975) for the national inventory of vegetation resources, as part of the classification of natural resources by the Department of Agriculture.

2.3 RELATIONSHIP BETWEEN GRASSLAND TYPES AND SOIL TYPES

Relatively little progress has been made in evaluating the relationship between grassland type and the nutrient status of the soil. Essentially two types of studies have been undertaken. The one has concentrated on the influence of soil nitrogen levels (Roux, 1954; Davidson, 1962; Altona, 1972) or forms of soil nitrogen (Wiltshire, 1972; 1973). This work was later expanded into the detailed biochemical investigation of species showing essentially different responses to nitrogen (see section 3.2). The other main approach has been that of investigating the correlation between vegetation changes and changes in the environment. Generally a large number of environmental factors has been recorded in such studies, often including soil nutrient status and pH. Of note here are the publications of Roberts (1963b; 1966; 1971) and Bredenkamp (1977). However, Bosch (1974; 1977; 1978) has studied more specifically the relationship between community type and soil type in the eastern Orange Free State, while Mostert et al (1971) have described the soil types typical in the Orange Free State region as a whole.

On the whole, the work done to date has been fragmentary and of limited general application. There is a need for a comprehensive classification of grassland types (see section 2.2), and a complementary need for effective correlation of these grassland types with a classification of soil types at an appropriate level of generalization (cf. MacVicar et al 1974). In the first place, some kind of definitive interpretation of the popular expressions 'sourveld', 'mixed veld' and 'sweetveld', in terms of soil-nutrient status, is required, cf. 'eutrophic', 'mesotrophic' and 'dystrophic' as defined in pedological terms.

2.4 RELATION BETWEEN GRASSLAND TYPE AND CLIMATE

van Zinderen Bakker (1978) has discussed Quaternary changes in the vegetation of southern Africa, which he believes are related largely to changes in temperature and in the amount of seasonality of rainfall. Acocks (1975) has also related the vegetation of South Africa to climate in a general sense.

More specifically, a number of workers have undertaken detailed studies of the vegetation/environment relationship at specific sites. These include studies by Roberts (1963b; 1966) for the Cathcart and Thaba Nchu areas, Herbst and Roberts (1974) for the alpine grasslands of Lesotho, and Bredenkamp and Theron (1976) and Bredenkamp (1977) for the Suikerbosrand Nature Reserve. Roberts (1971) has also described the habitat preferences of 27 grasses of the Orange Free State and Snyman et al (1980) have described the water relations of different successional stages of grassveld near Bloemfontein.

The effect of lightning, although no doubt of great importance, has received scant attention in South Africa. Only Komarek (1971) and Edwards (1984) have published directly in this field although, by

implication, much of the literature concerned with the effect of fire can be attributed to lightning (see section 5.4). The frequency and relative importance of lightning fires as an ecological factor in different parts of South Africa have been discussed by Edwards et al (1983). Since the rainfall over most of South Africa is low and plays a major role in determining the nature of the vegetation in any area, considerable involvement might have been expected in relating vegetation type to soil moisture conditions. However, work on soil water per se has been limited. More attention has, however, been given to the influence of the vegetation on the water yield from catchments and on soil erosion, to which it is closely linked. Here the publications of Bayer (1933), Wicht (1949; 1971), Banks (1961), Beard (1962) and Nanni (1972) should be noted. Peeling (1918) has discussed the effect of vegetation on rainfall, while modelling techniques for the estimation of soil loss have been produced (Anon 1976b) and tested (Schulze, 1979a).

Both C3 and C4 species are represented in South African grasslands. Vogel et al (1978) have discussed the distribution of Kranz grasses in South Africa, and Ellis (1977) the distribution of the Kranz syndrome in South African Eragrostoideae and Panicoideae. Particular attention has recently been given to Alloteropsis semialatis which has been shown to possess both C3 and C4 forms (Ellis, 1974; Frean et al 1980; Frean and Cresswell, 1981). Climatic factors are interpreted as controlling the distribution of C3 and C4 grasses (Vogel et al 1978). However, notwithstanding the value of the research that has been done, there remains a lack of a broad synoptic interpretation of the role of climatic factors on the distribution of grassland types. This appears to be particularly true of the influence of the intensity, duration and periodicity (seasonality) of moisture deficit and surplus, especially as a result of the interaction of rainfall and temperature.

2.5 FAUNA AND WILDLIFE RESOURCES

The grassland biome of South Africa is extremely rich in faunal species and the distribution of faunal species has been described in a number of publications. Some important references in this field include those on terrestrial fauna of South Africa (Bigalke, 1976), on animals of South Africa (Hewitt, 1923), herpetofauna of the Natal Drakensberg (Bourquin and Channing, 1980), terrestrial mollusca of the Mkuzi and Ndumu game reserves of Zululand (van Bruggen, 1970), hodo-terminated harvester (Coatin, 1958) and small carnivores (Rowe-Rowe, 1978) in Natal. The distribution of birds has been described for the midlands of Natal by King (1916), those of Natal and Zululand by Clancey (1964) and of South Africa by McLachlan and Liversidge (1970). Clancey (1967) has described the distribution of game birds. The relationship between bird populations and temperature and rainfall has been discussed by Bowen (1933) and between bird populations and vegetation by Liversidge (1962).

2.6 RARE AND ENDANGERED SPECIES

These have been described in a number of South African National Scientific Programmes Reports. Relevant publications are as follows:

- (i) plants. Hall et al (1980) list 1915 vascular plant taxa regarded to be either extinct or variously threatened in southern Africa. This represents 11% of the available plant taxa of the region.
- (ii) large mammals. Skinner et al (1977) list 22 threatened South African large mammals, one exterminated, eight endangered, one vulnerable, nine rare and three special cases.
- (iii) small mammals. Meester (1976) listed 49 small mammal species thought to merit conservation attention although none of these is considered to be endangered.
- (vi) reptiles and amphibians. McLachlan (1978) has identified 46 threatened South African reptiles and amphibians which deserve attention. Two of these are endangered, 10 vulnerable, 21 rare and a further 12 rare (peripheral) and one of unknown status.
- (v) aves. Siegfried et al (1976) provide information on 101 South African bird species thought to be eligible for conservation attention and a further 35 which may qualify for special attention.

3. ECOSYSTEM PROCESSES WITHIN THE GRASSLAND BIOME

3.1 SPATIAL AND TEMPORAL VARIATIONS IN THE DRIVING VARIABLES

Cook (1964) has described the pleistocene environment of southern Africa, and descriptions of recent climate of South Africa may be obtained by reference to publications by the Weather Bureau (eg Anon, 1976a) and by Schulze (1965).

Rainfall maps and a description of district rainfall have been published by the Weather Bureau (Anon, 1957; 1960) and Dyer (1975) has assigned rainfall stations to homogenous groups. Tyson (1978) has described rainfall changes over South Africa during the period of meteorological record. Such analyses have been used to establish rainfall cycles for the prediction of future rainfall patterns (Dyer and Tyson, 1977; 1978; Vines, 1980; Markham, 1980). The associated kinetic energy of rainfall has been described for South Africa by Schulze (1980a) and for the sugar belt of Natal by Schulze and Easter (1980). Levekind (1940) has described evaporation patterns from standard tanks.

Occasional attempts have been made to describe spatial and temporal variations in insolation, temperature, evapotranspiration rates, moisture conditions and humidity within particular grassland sites. At some of these sites the microclimatic conditions have been related to changes in community type in an attempt to establish the ecological significance of these factors. Allsopp (1945) investigated the effect of light intensity, soil temperature and soil moisture conditions on the nature and condition of grassveld in the vicinity of Pietermaritzburg. Schulze and McGee (1980) discussed climatic indices and classifications in relation to the ecology of South African vegetation, while Granger and Schulze (1977) examined the influence of radiation patterns on vegetation response in the Drakensberg. Roberts (1975) also worked in mountain terrain, where he examined the spatial and temporal variations in temperature, evaporation and humidity. He showed, for example, that frost-free sites exist even in these areas during winter. Aitken (1922) had previously undertaken a similar analysis in the vicinity of Pietermaritzburg.

The influence of agricultural practices on grassland micro-climate has not been extensively examined. Savage (1980) and Savage and Vermeulen (1983) have, however, reported on the effects of fire on grassland micro-climate, while van den Berg et al (1976) have investigated the influence of different grazing practices on moisture infiltration.

The grassland soils of South Africa have received considerable attention in recent years but little of this work has been directed specifically at its influence on the nature of grasslands per se. However, these data can be used to provide a reasonably comprehensive picture of the soil types of the grassland zones. More attention needs to be paid to the direct relationship between soil type and community structure and behaviour. Of note among publications on the geology and geomorphology of the grassland zone are those by du Toit (1948) on the geology of South Africa, and by King (1978) and Maud (1978) on the geomorphology of

central and southern Africa and of Natal and KwaZulu, respectively. van der Merwe (1962), Harmse (1978) and MacVicar et al (1977) have described the soils of South Africa, and regional surveys have been published by Harmse and Grobler (1966) for the Highveld region, by van der Eyk, MacVicar and de Villiers (1969) and Ludolf and Scotney (1975) for the Tugela Basin and Lions River and Mooi River soil conservation district, respectively. Sumner (1957) examined the physical and chemical properties of Tall Grassveld soils in Natal in relation to their erodibility.

The classification of Natal into bioclimatic regions by Phillips (1973) was based on spatial variations in the driving variables affecting community type. In particular humidity (rainfall) and temperature formed the basis of the classification, but major geological features, soil groups (including detail down to series level) and vegetation type was also described. Tainton et al (1976) described the common grass species within each of these regions, and discussed their ecology.

In the Orange Free State, Bosch (1974; 1977; 1978) has studied changes in community structure of grasslands, including differences in the successional development of communities on different soil series.

3.2 EFFECT OF DRIVING VARIABLES ON PERFORMANCE OF INDIVIDUAL PLANTS AND SWARDS

Much of our understanding of the influence of climate on plant behaviour must be inferred from work on either monospecific or mixed swards rather than on individual plants. Such work has generally been undertaken to examine the effects of a variety of clipping or other management orientated treatments on veld in different seasons. Plant production, measured as the yield of dry matter per unit of land area, has frequently been of prime consideration in this work, but not infrequently, developmental aspects of individual species have also been recorded. In general, however, the information which such work provides on the influence of climatic factors on plant development has arisen indirectly from such work. Exceptions to this are the early work published by Mes (1952; 1956) on the influence of climate on growth and seed production in some grasses, and the later analysis by de Jager, Opperman and Booyen (1980) of the effect of climate on the production of grassveld in the central Orange Free State. Stuckenbert (1969) discussed the role of temperature as an ecological factor and Rutherford (1978) has discussed more generally the ecology of primary production in southern Africa. General reviews of the production characteristics of individual species have been published for Antheophora pubescens by Donaldson et al (1972), for Themeda triandra in East Africa by Ndawula-Senyimba (1972) and for Eragrostis curvula by Rethman (1973). Seasonal response of this latter species to nitrogen has been reported by Nash and Tainton (1975), while Hackland and Jones (1980) have developed a model for the growth of this species, in which they relate production to those climatic factors which most influence its growth. Other publications which have involved general studies of growth and development but which have not been directed specifically at the effects of climate include those of Rabie (1954), Clark (1956), Rethman (1965), Bartholomew (1968), Rethman and Booyen (1969), du Toit J (1972), Grunow et al (1977) and Downing and

Marshall (1980).

Root growth of grassland species in relation to climate and soil conditions has received little attention in South Africa. Early work by Murray and Glover (1935) and Coetzee et al (1946) has not been followed up and a wide field remains open for investigation. In particular, the differential response of species within a community to soil moisture conditions, and through soil moisture to aspects such as temperature, insolation, nutrient status at different depths in the profile etc, needs close examination (cf. Bosch, 1974; 1978).

Not unexpectedly, perhaps, somewhat more work has been undertaken on the morphological development of the above-ground organs of grass plants than on their roots, but once again this work has been largely designed to trace seasonal change rather than to examine the response of tillers to specific climatic factors. For example, papers by Scott and Rabie (1956), Booysen et al (1963), Tainton (1958; 1964), Tainton and Booysen (1963; 1964a; 1964b), Rethman and Booysen (1967; 1968a), Steinke (1968), Low (1969), Rethman (1971), Opperman and Roberts (1978) and a review by Bridgens (1968) describe the work undertaken in this field in South Africa. Gibbs-Russell (1983) has discussed correlations between evolutionary history, flowering phenology, growth form and the seral status of important veld grasses.

Physiological investigations have generally been conducted to determine more specifically the influence of environmental conditions on the functioning of the plant, although in these studies also, the effects of defoliation have often been the prime objective of the research. The physiological work undertaken on individual plants has centred largely around the effect of inorganic nutrients on plant growth, aspects of photosynthesis and respiration in different plant species under different conditions and water use efficiency of veld plants.

Weinmann (1955) has provided a wide ranging review of the chemistry and physiology of grasses while Pienaar (1966) compared the nutrient uptake and growth response of four important species in the Transvaal. Henrici (1930a) examined changes in mineral content of grasses over the season and the influence of drought on mineral composition. Nitrogen sensitivity of indigenous, and particularly of climax veld species, had received some considerable attention since it was first shown at Frankenwald (Hall et al, 1937), and later at Ukulinga (Booyesen, 1954), that climax species were replaced by pioneer species when nitrogen was applied. Roux (1954) investigated the nitrogen sensitivity of individual species. This work was later expanded into detailed physiological work on the effect of nitrogen on plants in different successional stages of the highveld (Grossman and Cresswell, 1973; 1974; Tew et al, 1974; Wiltshire, 1972). Autumn remigration patterns of both nitrogen and phosphate have been described by Weinmann (1942), while Naidoo and Steinke (1979) have examined the influence of carbohydrate levels in the plant on phosphorus uptake. Henrici (1930b) compared the phosphorus content of grasses growing on different soils, and containing different amounts of phosphorus in the eastern Transvaal. Meanwhile, Wiseman et al (1972) investigated the influence of phosphate carrier, phosphate placement and the amount of lime applied to two oxisols in Natal on the growth response of Sorghum sudanense. This work also pointed to the effect of eliminating exchangeable aluminium from the soil on grass growth.

Generally in South Africa there has been little work on seed production, germination and establishment of indigenous grasses, in spite of the urgent need to improve the botanical composition of large tracts of veld by encouraging flowering, seed germination and seedling establishment among climax veld species. Most of the work on flowering has been related to defoliation. Only the review by Tainton (1969) and a report by Gibbs-Russell (1983) have dealt directly with the phenology of flowering in tropical/sub-tropical species. Similarly, little information is available on seed dormancy among veld plants and on the requirements of seedlings for survival. The only work published to date on breaking dormancy of veld plants is that by Cresswell and Nelson (1971; 1972) on the effect of micronutrients and gibberellic acid on dormancy and seedling metabolism in Themeda triandra.

Work on the rates of photosynthesis and respiration of veld plants has likewise received relatively little attention in South Africa, and indeed, on the native plants of sub-tropical and tropical areas in general. Brett (1941) described assimilation and respiration rates of some Natal grasses, Barnabas and Steinke (1975) studied the translocation of C-labelled assimilates in Eragrostis curvula and Ariovich et al (1981) the regulation of starch accumulation in Panicum maximum by nitrogen. de Jager (1971) proposed a theoretical model for describing the influence of weather variables on the photosynthetic rates of individual leaves. In this connection, the work of Grossman and Cresswell (1973; 1974) and Tew et al (1974) should also be referred to, as also that by Amory and Cresswell (1980; 1981) and Amory (1983) on the effects of nitrogen on carbon assimilation and of Wolfson et al (1982) on the influence of nitrogen and temperature on photosynthesis and photorespiration in Themeda triandra.

Since the early work of Weinmann (1940a; 1940b; 1944; 1948a), Weinmann and Reinhold (1946) and Diatz (1954) there has been considerable interest in the influence of carbohydrate reserves on growth and post-drought recovery rates of grass plants, and much of the philosophy of grass response to defoliation is derived from the results of this work. In spite of its considerable importance, however, little recent work has been published in this field. The report by Nursey (1971) on starch deposits in the roots and leaves of Themeda triandra (note similar work in 1938 by Mes and Bot), that on translocation patterns of C-labelled assimilates by Barnabas and Steinke (1975) and the work of Steinke and Booyen (1968) are the only recent reports available in this field.

Water relations among veld plants have received attention over an extended period of time. Most notable amongst the early work was the discussion of xerophytism by Henrici (1927) and the work by Mes and Aymer-Ainslee (1935) and Mes and Bot (1938), while Weinbrenn (1938; 1939) studied the osmotic values of leaf saps of certain highveld grasses. More recently Henckel (1964) has reviewed the physiology of plants under drought stress and Opperman and Roberts (1975), Opperman et al (1977) and Snyman et al (1980) have undertaken evapotranspiration studies on veld in the vicinity of Bloemfontein. Frean et al (1980) have studied the water efficiency of C3 and C4 forms of Alloteropsis semialata, while Rutherford (1980) has examined the production/precipitation relations in arid and semi-arid regions. In a more specialised area, Gaff and Ellis (1974) have worked on resurrection grasses whose foliage revives after dehydration.

3.3 EFFECT OF DRIVING VARIABLES ON THE RESPONSE OF COMMUNITIES

The work so far undertaken on the influence of the driving variables on plant response has been almost totally confined to the investigation of the response of individual species and only recently has work been undertaken on mixed communities. Of note here is the work on the Nylsvley project (Anon, 1978a) and the work recently initiated in the eastern Cape Province and at Bloemfontein (Snyman and Opperman 1983; Snyman et al 1980). Previously Marloth (1905) had reported on the influence of wind on vegetation in South Africa and Donaldson (1967) on the effects of the 1964/66 drought on the vegetation of study areas in the Vryburg district. Grossman (1982) has, however, pointed out a number of interpretive problems which makes a comparison of data derived in different ways unjustified.

3.4 INFLUENCE OF DEFOLIATION ON THE RESPONSE OF INDIVIDUAL PLANTS TO DRIVING VARIABLES

The influence of defoliation on the reaction of individual plants has been examined largely in one of three ways - morphologically, through an investigation of stem and leaf development; physiologically, through an investigation of carbohydrate status; and more generally in terms of overall yield response. Seldom, however, have these effects been linked directly to individual driving variables, which have remained uncontrolled in such trials.

Morphological investigations of the response of individual plant species to defoliation have been undertaken largely at Pietermaritzburg (Rodel, 1952; Clark, 1956; Scott, 1956; Tainton, 1958; Tainton et al, 1977), although more recently some work has been undertaken at Pretoria (du Toit, Rabie and Grunow, 1973; Pretorius et al, 1974). Carbohydrate work in South Africa has also been confined to only two centres and to only a few grass species. At Pietermaritzburg work on the influence of defoliation on the carbohydrate status of grass plants has been confined to Eragrostis curvula (Steinke and Booyesen, 1968; Bartholomew, 1968; Bartholomew and Booyesen, 1969; Steinke, 1969; 1975). At Bloemfontein, Opperman and Human (1977) and Snyman and Opperman (1983) have studied the influence of defoliation prior to and during periods of moisture stress on dry matter production, root mass and total available carbohydrates of Themeda triandra, while Roberts and Opperman (1966) discussed the influence of defoliation on perennial grasses as a whole. In Zimbabwe, Barnes (1960a; 1960b) has examined the influence of defoliation on root growth in Sabi Panicum (Panicum maximum) and Star grass (Cynodon plectostachys) and Barnes (1961) and Barnes and Hava (1963) have reported further on Sabi Panicum. A related aspect is the influence of defoliation on the performance of particularly unpalatable plants which often increase in abundance where veld is selectively grazed. Both Elionurus muticus (Brockett, 1983; Nel, 1983) and Aristida junciformis (Venter, 1968) have been researched with a view to establishing principles which would lead to the control, and possible elimination of

these plants from grassland swards.

Much of the work listed above also included an examination of the influence of defoliation on plant yield, an aspect which was also reported on by Burger et al (1975) for Antheophora pubescens. Clearly the main objective of this work has been to relate the results to practical management systems in which defoliation would largely be by grazing or fire. Barnes (1972) has, however, criticised much of this work on the grounds that it has in effect not simulated practical defoliation systems and he has called for increased emphasis on investigations of this type. This in turn requires a knowledge of grazing patterns, which have been reported on by Daines (1980), Gammon (1978b) and Gammon and Roberts (1978a; 1978b; 1978c), and of acceptability of different plants and plant parts (Theron, 1966; Theron and Booysen, 1966; Kruger and Edwards, 1972; Liversidge, 1972; Roos et al, 1973).

3.5 INFLUENCE OF DEFOLIATION ON THE RESPONSE OF COMMUNITIES TO THE DRIVING VARIABLES

As with the work on individual species, defoliation research on grassland communities has largely involved the investigation of cutting, grazing and burning treatments on yield, with some emphasis also on its effect on the botanical composition of the sward. Rodel (1952) and Tainton (1958) examined the influence of different intensities and frequencies of defoliation on the yield and species composition of a Tall Grassveld sward in Natal, and Rethman and Booysen (1968b) the influence of season of defoliation on the vigour of the same type of community. Jones (1967a; 1967b) has examined the influence of clipping on the competitive relationship between grass species. This work has provided some basis for an understanding of the consequences of defoliation patterns exerted by grazing animals which have been reported on by Daines (1980) in Dohne sourveld and by Danckwerts et al (1983) in sweetveld and by Gammon (1978b) and Gammon and Roberts (1978a; 1978b) in Matopos sandveld.

Grazing, as a means of applying defoliation treatments, has been widely applied but its effect on grassland yields has seldom been recorded, largely perhaps because of its major effect on species composition. As a consequence, yield measurements are often largely meaningless because of the major forage quality changes associated with changes in composition. However, Schoeman (1939), van Rensburg (1941), Vorster (1975), Tainton (1972), van den Berg et al (1975) and Vorster and Visagie (1980) have reported on the influence of grazing on veld yield and composition, and Booysen (1966) has presented a physiological approach to pasture research in which he analysed the relative effects of heavy versus lenient defoliation on forage production.

As with grazing, burning trials have been undertaken widely and over a long period of time in South Africa. Nonetheless, precise data on the influence of fire on grassland production is disappointingly scarce. Downing and Marshall (1983) have reported on the effects of burning and grazing on the survival of Themeda triandra in Dohne sourveld and have described differences in phytomass of roots and shoots and of a number of chemical constituents in the root material of grassland subjected to a range of defoliation treatments. Long term yields and changes in species

composition have been recorded at Ukulinga (Dillon, 1980) and Theron (1937) and Robinson et al (1979) have reported species changes due to fire in semi-arid grasslands. Rutherford (1976) has examined seasonal herbaceous biomass changes in burned, ungrazed woodland over the season, and Scotcher et al (1979) and Scotcher and Clark (1981) have discussed fire ecology in the Natal Drakensberg. More generally, Stuart-Hill and Mentis (1982) have discussed the role of the two most important defoliating agents, herbivory and fire, in the evolution of African grasslands and pointed out the different responses which these two methods of defoliation would be expected to elicit.

3.6 ROLE OF FIRE, HERBIVORY AND DECOMPOSITION ON SOIL WATER AND NUTRIENTS

No results have been published in South African grasslands outlining the influence of decomposition of organic matter on soil water and soil nutrients and these aspects still await consideration by researchers. Some results on the influence of seasonal grazing by sheep on the infiltration of water have been published (van den Berg, 1972; van den Berg, Roberts and Vorster, 1976), but this aspect also has been poorly researched. The influence of fire on soil water and nutrients has, however, received rather more attention. Cook (1939) examined the influence of grassland fires on both the water and nutrient status of soils, as did Mes (1958) and Cass (1978). Coutts (1945) and White and Grossman (1972) have reported on the effects of fire on the nutrient status of soils, while I'Ons (1960) examined the influence of burning at different times and at varying frequencies on rainfall infiltration and the moisture budget of soil under grass.

3.7 INFLUENCE OF ABIOTIC AND BIOTIC FACTORS ON RATES AND INTENSITIES OF FIRE, HERBIVORY AND DECOMPOSITION

Once again, this remains an area which has been largely unexplored except for recent intensive investigations by Trollope (1978a) and some work by Dillon (1980) on the influence of abiotic and biotic factors on fire behaviour. In Trollope's work, fire behaviour has in turn been linked to the effectiveness of grassland fires in killing encroaching bushveld, macchia and karroid species.

3.8 INTERRELATIONSHIP BETWEEN ANIMALS AND PLANTS

The general close relationship between the life history and behaviour of animals and the nature of the community in which they live is understandably taken for granted among ecologists, and in many papers references are made to aspects of this relationship. However, a number of researchers have specifically examined aspects of this relationship, and these include, in particular, the work by Davidson (1942) and Gandar (1980) on the association between insects and vegetation, and by a number

of researchers on aspects of antelope/vegetation relationships (Riney and Kettlitz, 1964; Skinner, 1970; Hofmeyer, 1970; Mentis, 1972; 1980a; Rowe-Rowe, 1972; Pienaar, 1974; Grunow, 1980; Gandar, 1980). Stuart-Hill and Mentis (1982) and Acocks (1979) (for the western regions of South Africa) have concluded that herbivores have had a major influence on the evolution of the grasslands of South Africa. More specifically, however, much work has recently been published on the influence of stocking rate of domestic animals on the nature of grasslands and on animal performance. This aspect is dealt with more fully in section 5.4.

4. GRASSLAND DYNAMICS

4.1 CHANGES TAKING PLACE BETWEEN GRASSLAND AND OTHER BIOMES

In 1938 Phillips reported on vegetation change in South Africa and suggested means of controlling this change. However, the most comprehensive analysis of major vegetation changes in South Africa is that published by Acocks (1975) in which he presented vegetation maps compiled from admittedly scanty evidence on the vegetation as it existed in South Africa in the year AD1400, the vegetation of South Africa in 1950, and a prediction of what it will be like in the year AD2050. Acocks (1975) also described changes between many adjacent veld types and provided what he believed to be the main reasons for these changes. In particular, he provided evidence for the encroachment of plants of the karoo, fynbos and savanna biome into grassland, and the conversion of forest to grassland. Danckwerts (1979) has recently reviewed these changes and in particular discussed their cause and their implications to production. Other work which throws light on the reasons for the invasion of plants from surrounding biomes into grassland is that detailing the behaviour of species from other biomes which are major encroachers into grassveld. These include in particular the work on encroaching bushveld species through an analysis of plant succession in such areas (Bews, 1918b; Aitken, 1921) and more directly on the factors which are responsible for the successful establishment of and the control of species of *Acacia* (van der Schijff, 1964; du Toit, 1967; 1972b; Trollope, 1974), the work on karroid species (Trollope, 1978b) and on macchia species (Cohen, 1940; Hatting, 1953; Krupko and Davidson, 1961; Trollope and Booysen, 1971; Trollope, 1973; 1980). Also dealing with the extent of and main reasons for karoo encroachment into grassland are the report of the Drought Investigation Commission (Anon, 1923) and papers by Tidmarsh (1948) and Acocks (1964). Conversely, grassland has replaced forest in many areas but this process has not been investigated directly. However, the converse, i.e. the conversion of grassland to forest, has received some attention, particularly in the Drakensberg of Natal (Granger, 1976; Westfall et al, 1983).

Additional references which may throw some light on vegetation changes in South Africa are those of Fair and King (1954) on the erosional land surfaces in the eastern marginal areas and of Phillips (1965) on some ecological and related changes in trans-Sahara Africa.

4.2 CHANGES TAKING PLACE WITHIN GRASSLANDS

Scott (1951), Bayer (1955), Acocks (1975) and Danckwerts (1979) have outlined the changes which have taken place in the vegetation of South Africa. Shantz and Turner (1958) have based an analysis of vegetation change on comparisons of photographs taken in 1956 and 1957 with photographs of the same sites taken between 1919 and 1924. These authors concluded that they had difficulty finding "natural" undisturbed stands, and that where these could be identified they were nearly always confined

to rocky or inaccessible sites. They attributed change to the clearing of vegetation and the use of fire to prepare land for arable use, and to excessive grazing by domestic livestock. Story (1952) has also reported on changes which have taken place in the vegetation of the Keiskammahoek district, and his conclusions may be applicable over large areas of the grassland biome, while Jarman and Bosch (1973) have examined the extent of karoo invasion into grassland.

Work detailing changes within grasslands is largely that which has set out to examine the influence of various management (burning, clipping, grazing) treatments on the species composition of particular grassland types, or that which has been undertaken to examine particular problem grassland species. In the latter category, are papers by Opperman and Roberts (1974) on Elionurus muticus, by Venter (1968) and Edwards et al (1979) on Aristida junciformis, by Hildyard (1967) on the control of the poisonous plant Senecio retrorsus in grassland, and by Coetzee (1972) on the control of Pachystignea pygmaeum.

Reports on treatment effects on the nature of grasslands at specific sites include those of Rethman et al (1971) and Malherbe (1971) for the north-eastern sandy highveld, Tainton (1972), Tainton et al (1978) and Dillon (1980) for tall grassveld in Natal, van den Berg et al (1975) and Coetzee (1975) for Cymbopogon - Themeda veld, and Edwards (1968), Granger (1976), Scotcher et al (1978) and Scotcher and Clarke (1981) for highland sourveld. Van der Schijff (1964) and Scott (1967) have reviewed the role of bush encroachment into grassland from adjacent areas of savanna in South Africa. Also, considerable changes in the species composition of grasslands has been shown to result from the application of fertilizers. To date, however, this practice has not been widely used, and so has not contributed to major changes within grasslands. Reference will, however, be made to the effects of applying fertiliser to natural grasslands in section 5.4.

Additional analyses throwing some light on botanical changes within the grassland biome include those of Potts (1923) and Davidson (1964), who reported on plant succession in the Orange Free State and the Transvaal highveld, respectively. Weisser (1978) has reported on changes in the areas of grassland on dunes between Richards Bay and the Mfolozi River over a period of 37 years, and Morris and Muller (1970) on seasonal variations of grassland basal cover. This aspect, together with analyses of composition changes, has also been researched by Foran (1976), Foran et al (1978), Tainton et al (1978), Tainton et al (1980) and Mentis (1983) in their work on the development of a method of veld condition assessment for the humid grasslands in Natal. Mentis and Tainton (1981) have discussed the stability and resilience of the humid sour grassvelds under continuous grazing.

The above listing of published work on botanical changes within the grassland biome is not impressive. It is therefore surprising to find an impressive list of reports on techniques of determining the structure (cover and species composition) of grasslands. These are included in this report for the convenience of research workers wishing to examine changes in grassland communities. Grunow (1966) and Grunow et al (1969) have discussed objectivity in plant community classification and the practical implications of ordination and classification. Wheel point methods of vegetation survey have been described by Tidmarsh and Havenga (1955), Roux (1963) and von Broemsen (1965), the dry weight rank method

by Barnes et al (1982) and the use of microplots for the estimation of basal cover by Tiedeman and Weiland (1983). Miller and Booysen (1968) examined a method of delineating plant communities in a relatively homogenous grassland, Thompson (1975) described a photographic technique to quantify lateral cover density, van der Walt (1962) described the results of an association analysis undertaken in the Sneeuberg, and Jones and Bartholomew (1971) means of measuring the spread of plants from a focus. West (1936) and Walker (1970) compared a number of methods of analysing grassveld, and veld condition assessments, whose importance lies largely in the presentation and interpretation of species composition and cover data have been discussed by Roberts (1970), Roberts and Opperman (1974), Roberts et al (1975), Foran et al (1978), Tainton et al (1978), Tainton et al (1980), Mentis et al (1980), Vorster (1982) and Westfall et al (1983).

Soil erosion and major changes in the nature of plant communities over much of the land surface in the grassland biome since permanent settlement have had often dramatic effects on the nature of soils and on streamflow patterns. Work in this area has not been extensive with the exception of that undertaken in the Drakensberg Conservation Area and reported on by Scott (1951), Pentz and Scott (1952), Scott et al (1955) and Pentz (1963). Research on streamflow as influenced by the management applied to catchments has also been undertaken at Cathedral Peak in the Natal Drakensberg, and papers by Bosch (1980), Bosch and Hewlett (1982), Nanni (1960), Granger (1976), Schulze (1974; 1979b) and Wicht (1971) describe this work.

4.3 RATE AT WHICH CHANGES ARE TAKING PLACE

Acocks (1975), Shantz and Turner (1958) and the report of the Drought Investigation Commission (Anon, 1923) have provided some estimates of the rates of vegetation change in South Africa, and the report of Story (1952) throws light on the rates of change of sweet and sour grassveld which is mismanaged. Rates of change in the nature of grassland may also be inferred from much of the experimental work referred to in section 4.2. Such work has shown that the composition and production of grassland may change rapidly when it is subjected to stress conditions. As an example, the yield of a Tall Grassveld community in Natal has been found to decline to 30% of its original after six years of grazing at twice the recommended grazing capacity and dramatic changes in composition have been shown to occur in less than this period (Tainton, 1972). More generally, Jones and Cross (1971) have shown the extent to which differential intensities of defoliation of different species in a mixed community is able to drastically alter the balance of the species in such a sward. Also, changes in both basal cover and in species composition in response to the application of nitrogen have been noted in as little as two years (Booyesen, 1954). Yield responses are almost immediate and often dramatic. Changes towards higher seral stages are, however, normally relatively slow but are closely related to the growing conditions, and particularly the rainfall, at any site. Such rates are implicit from the reports of Edwards (1961) and Booyesen (1954).

The lack of any substantial body of precise information on rates of change in South African vegetation is likely to have resulted at least in

part from the lack of suitable and widely accepted techniques to measure change. Such techniques are, however, now available (Foran, 1976; Foran et al 1978; Mentis, 1983) so that work in this field can now be readily undertaken. The measurement of rates of change in soil conditions, which has such an important bearing on rates of change of the vegetation, is, however, difficult and little work has been done in this field. Edwards (1961) discussed the effect of burning and mowing on soil loss in the Tall Grassveld at Estcourt in Natal, and I'Ons (1960) and Cass (1978) have reported on the effects of fire on soil surface characteristics and infiltration rates. van den Berg et al (1976) have undertaken similar studies in relation to the effects of seasonal grazing by sheep. Other reports which may throw some light on the rates of soil loss, and so changes in soil conditions and runoff of water from grassland, are those of Scott (1951) and Scott et al (1955). Rates of recovery of both soils and streamflow may be inferred from papers by Pentz and Scott (1952) and Pentz (1963).

4.4 MAJOR CAUSES OF CHANGE

While there can be no doubt that there have been major climatic changes in South Africa over geologic time, there is no evidence that these changes retain an influence on the general distribution and characteristics of the present day vegetation (Adamson, 1938). These changes are apparently so ancient that the present flora has reached a state of equilibrium with existing climate (Adamson, 1938), although some species of plants do appear to be relics of ancient climates (Goldblatt, 1978) and it needs to be appreciated that Iron age man is likely to have had an important and ever changing effect on the vegetation (Feely, 1980; Hall, 1984). Changes in general climate can, apparently, be largely ruled out as having contributed to recent changes in the vegetation (Anon, 1923; Shantz and Turner, 1958). However, the possibility does exist that recent denudation of large tracts of land has itself had an impact on local climate (Tidmarsh, 1952).

Recent changes in the vegetation of South Africa are widely ascribed to three factors: bad grazing practise, the incorrect use of fire and the clearing of woody plants (Anon, 1923; Acocks, 1975; Werger, 1983). Pentz (1945) and Scott (1951) attributed vegetation change largely to bad land-use practises which resulted from, among other things, an optimistic assessment of the suitability of land for intensive agricultural use. This has resulted in a supposed dramatic increase in the rates of soil loss and a consequent desiccation of the environment, resulting in a substantial decline in the resource base. Research in this field has, however, been limited and few quantitative data on rates of soil are available, and there is a poor understanding of the mechanics of erosional processes (Garland, 1982).

Changes in the vegetation which have resulted from bad grazing practise have been discussed by Shantz and Turner (1958), Roberts (1969a), Tainton (1972; 1981a) and others. This has involved such factors as overgrazing, selective grazing and the use of the incorrect type of animal (Roberts, 1969a). Acocks (1966; 1975), in particular, attributes much of the recent degradation of grassland to selective rather than overgrazing, and he cites the continued presence of decreaser species in

heavily grazed grasslands of the African homelands as evidence for this. In general, however, it has been the over-use of grasslands through overstocking which has been largely blamed for the largescale retrogression of grasslands.

In spite of this, it is only recently that any serious attempt has been made to develop methods of establishing appropriate stocking rates of different types of veld. Early work on veld management concentrated almost exclusively on the need to apply a variety of grazing systems (Scott, 1947; 1955).

The role of fire in influencing the nature of the South African vegetation remains controversial. There is no doubt that it has for long been a major factor in shaping the structure and composition of this vegetation (Hall, 1984) and recent changes in the vegetation may be ascribed either to present day under-use or over-use of fire or to incorrect management procedures adopted during the recovery period of burnt vegetation (Theron, 1937; Story, 1952; Trollope, 1978b; 1983; Tainton, 1978; 1981b; Tainton and Mentis, 1984). Also, the exclusion of browsing animals from the veld which is subject to scrub invasion during the recovery period following a burn is believed to encourage the change from grassland to bushveld (Trollope, 1980).

The denudation of the soil surface through overgrazing and trampling or through increased rates of eradication of vegetation for the creation of arable lands may give the general impression of a less favourable climate than actually exists (Adamson, 1938) and may bring about a devastating and virtually irreversible change to the environment, particularly in the arid zones (Werger, 1983). The impact of such changes on the future prosperity of the peoples of South Africa is likely to be considerable and the precise definition of the causes of vegetation change and the means by which it can be prevented remains a major challenge.

5. MANAGEMENT AND UTILIZATION OF THE GRASSLAND BIOME

5.1 DESCRIPTION OF RESOURCES IN RELATION TO LAND-USE POTENTIAL

Pole Evans (1920) was the first South African to describe the resources of the veld in terms of livestock production, and some assessment of the value and possible uses of this resource were subsequently provided by ecologists who classified the vegetation types of South Africa (Pole Evans, 1936; Adamson, 1938; Pentz, 1949). Pentz (1949), who identified the resource factors which govern land-use potential, and outlined the manner in which each resource factor affects land use potential, pioneered land use classification in Natal. Scott (1951) later provided a comprehensive analysis of the land use/resource relationship when he reported on the results of research work in the Drakensberg conservation area in Natal. Phillips (1959) reported more widely on the development of the Agricultural potential of Africa south of the Sahara, and subsequently undertook a comprehensive analysis (Phillips, 1973) of the land use potential of the different ecological zones in Natal. The current situation in Natal has been outlined by Scotney (1978).

Planning for nature conservation has received some considerable attention, and reference should be made to van Vuuren (1961), Steyn (1961) and Walker (1974; 1976) for information on this topic.

5.2 PROJECTIONS OF FUTURE LAND-USE PRACTICES

It is logical to expect that land-use practices will intensify as the demand for food by the growing population increases, and so projections of future land-use practices must develop from an analysis of the potential of different areas for agricultural intensification. Such analysis sets the theoretical limit to intensification and is therefore of major concern, although it is true that the extent to which such potential is ever realized will depend on social, political and economic circumstances. Indeed, such circumstances may, and often do, encourage over-intensification, which in many instances leads to resource degradation. In particular, many land-use practices which lead to degradation in the long term, are financially highly rewarding in the short term, and herein lies one of the major stumbling blocks to any attempt to reduce land exploitation.

Since it is not possible to predict the possible changes in social, political and economic patterns, their effects on future land-use patterns are not possible to define. Nonetheless it is vitally important to identify the potential of any agricultural region, since this determines the land-use patterns which need to be encouraged and provides the basis for legislation control of land-use. Such classifications of land-use potential are those by Pentz (1938; 1945), Scott (1951), Phillips (1959; 1973), Anon (1970), Scotney (1971) and Edwards and Booyesen (1972). Assessments of the potential in different areas for the replacement of natural veld by sown pastures have been published by

Edwards (1966; 1972b; 1978), Booysen (1970; 1978; 1980), Theron et al (1974), Theron (1975) and Edwards et al (1980).

As already suggested, however, such classification of land-use potential, and in particular the limits to which intensification is advisable in any area, have often been ignored in the past. In an analysis of the reasons for this, it is necessary to distinguish between commercial and subsistence farming. In the former, land-use practice will in a large measure be dictated by economic considerations and bad land-use practice will continue so long as it continues to be economic. There are, however, other factors which have been implicated in encouraging development in particular, and often unacceptable, directions. These include complacency, an inefficient agricultural extension service and the recommendation of unacceptable practices (Roberts, 1969a).

In subsistence agriculture, land-use practice is largely dictated by social and political considerations. In such circumstances the financial advantages of relating land-use practices to the resource potential of an area are of less importance than in commercial farming. Here future land-use patterns are difficult to predict, but an assessment of the potential of such areas is nonetheless important in production planning. These have been taken into account in planning exercises undertaken by staff of the University of Fort Hare (Anon, 1978b) and by Trollope (1982; 1984) in planning development strategies for the Ciskei, by Thorrington Smith et al (1978) and Bromberger and Lea (1982) in their consideration of land-use in KwaZulu, Makhanya (1979) in his discussion of agricultural development in Lesotho, and in the planning of agricultural development in the Tugela basin region of Natal (Phillips, 1973).

A rather special case for the modification of current land-use practice is that provided by the possibility of using veld for the production of game. While it is generally conceded that domestic animals provide a higher income than game when farmed alone, the possibility exists for an integration of game into systems now based entirely on domestic animals (Walker, 1976; Collinson, 1979).

5.3 LIMITATIONS TO LAND-USE WHICH EXIST OR ARE LIKELY TO ARISE

A host of factors, related both to the physical conditions within a region and the social, political and economic situation of the peoples which inhabit the region, act in determining its agricultural production. The social, political and economic factors act largely in determining the extent to which the potential of an area can be realized, and will not be considered further. Rather, the factors which limit the potential of an area will be outlined. These include climate (and particularly low rainfall and associated droughts), soil factors (both physical and chemical) and topography.

Much recent work in South Africa has been funded by the Water Research Commission, who have presented a number of important publications in this field. For example, Schulze (1982) has published on the agrohydrology and climatology of Natal in which considerable detail is given on the precipitation, temperature and evapotranspiration patterns. These data then lead to an evaluation of land-use potential determined by these

physical factors in the Natal region. Also, the supplementary irrigation requirements for different seasons are identified. Other publications which may be referred to in this respect are the following: evapotranspiration (Clemence and Schulze, 1982); the hydrology and water resources of the Drakensberg (Schulze, 1979b); the determination of rainfall seasons in South Africa (McGee, 1977); rainfall frequency and distribution (Onesta and Verhoff, 1976); estimation of storm runoff in KwaZulu (Schulze, 1981); irrigation scheduling (Mottram and Minnaar, 1975; Hensley and de Jager, 1982) and the distribution of climatological factors of importance to agricultural planning in Natal (de Jager and Schulze, 1977).

The surface water resources of South Africa have been described for the eastern escarpment by Pitman, Middleton and Midgley (1981). This publication, like that of Schulze (1982), describes also the major physical characteristics of a number of drainage regions and the extent to which the hydrology may affect afforestation and irrigation development. The question of cooperative water resource development has been discussed by van der Riet (1980) and Schulze (1980b) has discussed the relationship between land-use and hydrological factors.

The only other climatic factor in the grassland biome which is likely to greatly influence agricultural production is temperature. This factor has been discussed by both Phillips (1973) and Schulze (1982) for Natal, and data are available for the South African region in reports of the Soil and Irrigation Research Institute (Anon 1975a) and elsewhere. The physical resource base leans heavily on soil characteristics, whose influence on land-use potential has been discussed by Orchard (1954), Loxton (1966), Ludolf (1970), MacVicar et al (1974) and, in relation to potential for pasture production, by Edwards and Scotney (1978). These analyses are, however, largely concerned with the suitability of land for various forms of intensification. In this respect, both the loss of topsoil in the past (Anon, 1923; Ross, 1963) and the potential for accelerated erosion with disturbance of the natural vegetation, impose limits on intensification, unless considerable effort and funds are expended to modify the prevailing physical conditions of the area (Edwards et al, 1980).

Over much of South Africa, land-use patterns are largely determined by the current condition of the natural vegetation since large areas are too arid, too stony or topographically unsuited to intensification. These natural resources have been described by Pole Evans (1920), Scott (1951), Pentz (1949), Acocks, (1975) and Phillips (1973). Early reports published Hall (1934) and by the Department of Agriculture (Anon, 1938; 1940; 1951) provided early analyses of the problems and possibilities of developing the grasslands of South Africa, and Edwards D (1972) provided an assessment of the use of botanical surveys in Agriculture.

For conservation and recreational purposes, Edwards (1974) has provided an assessment of the adequacy of conserved areas in each of the Veld Types, while von Richter (1974) has considered the adequacy of existing areas for the range of wild animal species which needs to be catered for.

5.4 OPTIONS IN ALLOCATING RESOURCES TO IMPROVED LAND-USE AND GRASSLAND RESPONSE TO THESE OPTIONS

Objectives of management

Land-use may have a number of objectives in any given situation. In general, however, its main objective over a major part of the land surface is the optimum use of land for the production of food and the production of good quality water for domestic and industrial use. On limited areas, the provision of sanctuaries for wildlife, the preservation of the status of sample ecosystems and the provision of 'natural' areas for recreation become paramount in the identification of objectives of management. All these, and other, objectives operate within the constraints of conserving the resources of any area, and in particular the soil, since this forms the base on which all other objectives ultimately depend.

Maximising food production may involve either the development of appropriate technology for the management of and the production of food from natural communities, or the replacement of such communities by plants which are potentially more productive than those of the natural community. Certainly, it is logical to examine the possibility of replacing natural communities where conditions are such that more productive communities can be established, but such modifications need to be restricted in scale until there is an assurance that they will not lead to resource degradation. Over much of South Africa conditions are such that vegetation replacement is unlikely to be successful and so management of natural vegetation remains the focus of grassland research in such areas. This is true even in areas of high biological potential where economic, political and social constraints may operate to restrict the development of an area to a fully intensified state or, even worse, where these constraints operate to prevent this from being done efficiently. Where this occurs, the resultant vegetation may often be such that none of the objectives listed above are realised, and indeed the resource base may suffer considerably in the process.

Management options

Increasingly management options have been viewed in a holistic manner. This concept, discussed in some length by Smuts (1926), has been applied more specifically to grassland systems by Edwards (1972a), Jones (1978) and Mentis (1980b). Grunow (1973) has detailed research relating to the management of South African ecosystems. However, the Savanna ecosystem project undertaken at Nylsvley (Anon, 1975; 1978a; Huntley and Morris, 1978) serves as the most ambitious project of this type in South Africa to date.

Grassland management

1. Research approach and techniques

Much of the past research on grasslands in South Africa has been directed at the individual components of management systems and a considerable volume of work has been published on the different facets of grazing management (for the definition of terms used in describing the components of grazing management systems refer to Booysen (1967) and Edwards (1973)). Such work often requires the development of specific techniques for the effective investigation of individual reactions, and a description of the techniques used will normally be found in the publications outlining the results of each investigation. However, papers specifically directed at an examination of the techniques which may be used in grassland research have been published locally and those appropriate to grassland management will be referred to here as an aid to intending researchers.

Methods which have been used to measure plant production and plant response to manipulation have been reviewed by Symons and Jones (1971), while Edwards (1965) and Muzzell and Booysen (1969) have described the use of the light-proof box to measure plant vigour. Bransby (1975) and Tainton (1977), and Danckwerts and Trollope (1980) have described the use of the disc meter to measure plant production while Sander (1970) has discussed the use of the capacitance meter for the same purpose. Animal based methods include the use of the oesophageal fistula (Bredon et al 1970). Animal performance remains, however, the most acceptable means of recording the effects of grassland manipulation on productivity (Edwards, 1969). Trials sufficiently large to provide reliable animal performance data are, however, expensive and are therefore unlikely to be widely used. For this reason mowing or some form of clipping has often been used to simulate grazing although the use of the mower to defoliate veld has often been used to simulate hay or silage producing systems, where it is clearly entirely appropriate. As a method of simulating grazing it is generally far less appropriate although it may be useful under certain circumstances.

2. Effects of mowing and burning

Reports on the effect of mowing on the productivity of grassveld have been presented by Louw (1938), Weinmann (1943; 1969), Fisher (1954), Tainton et al (1970) and Kruger and Smit (1974). Mutandaedza (1976) has examined the effect of frequency and height of clipping Hyparrhenia filipendula and Heteropogon contortus. Additional references, in which mowing has been compared with burning as an alternative method of removing accumulated material, are those of Venter (1962), Steinke and Nel (1967), Edwards (1968), le Roux (1968), Tainton et al (1978), Drewes (1979) and Drewes and Tainton (1981). In general these trials have shown that mowing is superior to burning as a removal treatment, but in many situations it is impractical. Fire is generally accepted as a factor which has for long shaped the nature of South African grasslands. Archeological evidence suggests that it was extensively used by early man in the management of grasslands (Hall, 1984), and analysis of lightning-strike density suggest that lightning is likely to have been a

regular ignition source (Edwards, 1984). Analyses undertaken by Edwards et al (1983) show that large areas of grassland in South Africa are burnt annually. It is not surprising, therefore, that burning per se has received considerable attention from researchers in South Africa for upwards of 60 years and continues to receive a great deal of emphasis on land used for domestic livestock, wild-life and in water-catchment areas, and here its effect on the species composition and the cover of grassland and on yield have been of primary concern. More recently, however, its effect on shrub invasion has received considerable attention. Phillips (1920) was the first to describe the results of formal burning trials, which he had undertaken at Groenkloof in the Transvaal, and since that time a large number of reports and speculative articles have been published (Marloth, 1924; Phillips, 1930; 1936; Staples, 1930; Anon, 1933; 1956; 1959; 1968; 1972b; Liebenberg, 1934; Thompson, 1936; Gill, 1936; Coetzee, 1942; Pentzhorn, 1942; Botha, 1945; Davidson, 1951; 1952; Diatz, 1953; Mostert and Donaldson, 1956; Edwards, 1961; 1969b; Tainton, 1963; 1978; Phillips, 1965; West, 1965; Scott, 1966a; 1970; 1971; van Rensburg, 1972; Mentis et al, 1974; Joubert, 1977 and Trollope, 1978b). Nanni (1960; 1969; 1970) has discussed the effect of fire on streamflow and water yield from mountain catchments, Scott (1967), du Toit (1972b) and Trollope (1974; 1978b; 1980) the role of fire in controlling bush encroachment, Mentis and Bigalke (1979) the influence of fire on grassland francolins and Mentis and Rowe-Rowe (1979), its effect on rodents. The associated effects of grazing and burning have been discussed by Glover and van Rensburg (1978).

The role of fire in the biomes of South Africa has recently been the subject of a programme undertaken by the CSIR under the auspices of the Scientific Committee on Problems of the Environment. The culmination of this international programme is the publication of "Ecological effects of fire in South Africa", edited by P de V Booyesen and N M Tainton (Booyesen and Tainton, 1984). Its 17 chapters review, in some detail, the effects of fire in South African biomes, including its role in the grassveld areas.

3. Grazing and grazing systems

An analysis of the effects of grazing on the nature and production of grassveld inevitably requires emphasis of a number of separate components of the grazing effect. Of major concern has been the effect of intensity of utilization (Hall, 1931; Weinmann, 1948b; Roux, 1967) and season of use (Janse van Rensburg, 1939; Venter and Drewes, 1968; du Toit and Ingpen, 1970; Kirkby, 1971; Rethman et al, 1971; van den Berg et al, 1975 and Bailey and Mappledoram, 1983). These effects have generally been examined by monitoring their effect on the vigour of recovery growth or on long-term changes in species composition. Of interest in this connection is the contention by Walker (1980) that at least periodic severe or excessively intensive grazing is necessary for the maintenance of the resilience of a grassland community.

(i) Grazing systems

As a result of the research undertaken on components of grassland management, as well as a good deal of speculation, veld researchers in South Africa have almost without exception, recommended rotational rather than continuous systems of grazing natural vegetation with domestic

livestock. However, as early as 1921 Stead outlined the value of paddock systems. Subsequent analyses of grazing systems have been published (Staples, 1930; Scott, 1947; 1955; Preller, 1948; Booysen, 1956; Davidson, 1965; Tidmarsh, 1957; Roux, 1968; de Jager and Joubert, 1968; Pienaar, 1968; du Toit, 1969; Venter and Drewes, 1969; van Tonder, 1969; Booysen, 1969; Roberts, 1969c; 1970; Mostert et al, 1971; Anon, 1972a; 1980; Booysen et al, 1975; Coetzee, 1975; Bransby et al, 1977 and Booysen and Tainton, 1978). Matthews (1950) described the basis of a grazing system which led to remarkable recovery in the condition of semi-arid grassveld in the eastern Cape Province. The purpose of the systems which have been recommended has almost exclusively been to ensure the maintenance of long-term production through the retention of acceptable and productive decreaser species in the community, rather than on short-term livestock production. The justification for this approach is that once the productive and acceptable species have been replaced by unproductive and unacceptable species, recovery to an acceptable composition is extremely slow and in some grassveld types the inferior species are extremely resilient. Such degradation of species composition therefore results in a serious long-term loss of productivity which will invariably override any short-term advantages to animal production of particular grazing procedures. The particular rotation procedures which should be adopted have, however, been the subject of much controversy. Acocks (1966) recommended the non-selective grazing approach; Pienaar (1968) the controlled selective grazing approach, and Howell L (1976), Howell D (1976) and Booysen (1966) developed the concepts of High Performance and High Utilization grazing which have been further discussed by Booysen and Tainton (1978) and Tainton (1981).

(ii) Selective grazing

At the centre of most discussions of management systems in South African veld has been the concern expressed of the detrimental effect of selective grazing. Not surprisingly therefore, grazing patterns of different animal species under different management regimes have received considerable attention from researchers (Hildyard, 1960; 1970; Jones and Cross, 1971; Liversidge, 1972; Edwards, 1975; Gammon, 1978b; van der Westhuizen et al, 1978; Daines, 1980; Danckwerts et al, 1983). The use of different ratios of domestic animals to reduce the degree of selective grazing has also been examined (Malherbe, 1971) and du Toit (1972c) and Aucamp (1976) have examined the role of the goat as a browser in areas subject to shrub invasion.

(iii) Sub-division into camps

In order to apply rotational grazing management procedures, the veld needs to be adequately subdivided and much controversy has arisen as to the number of camps which need to be provided to each group of animals in order to apply the recommended procedures. An analysis of the optimum number of camps in such systems has been presented by Booysen et al (1974) and Tainton et al (1977) have provided evidence in support of their conclusion that eight camps are normally adequate for rotational systems on veld from a grazing trial at Ukulinga. However, a number of authors have recommended systems involving large numbers of camps (multi-camp system) (Acocks, 1966; Anon, 1969; Howell L, 1976; Savory, 1978). Roberts (1970) has analysed the objectives of multi-camp layouts, while working in Zimbabwe, Denny et al (1977), Denny and Steyn (1977) and Denny and Barnes (1977) have compared rotation systems involving

different numbers of camps. Meanwhile, resting programmes for incorporation into rotational grazing systems have been discussed by Tainton (1971).

(iv) Grazing capacity

Another major component of research into veld management, other than the operation of the system itself, has been on grazing capacities and on the appropriate degree of utilization of veld. For many years, however, no active work was undertaken on grazing capacity since it was believed that, from the point of view of the maintenance of veld condition per se, any stocking rate could be used provided an appropriate rotational grazing and resting system was used. Farmers would therefore adjust their stocking rates on the basis of animal performance, and the long term condition of the veld would be maintained. While this approach is no doubt acceptable in theory, in practice many farmers have not adopted rotational grazing methods (Roberts, 1969a), and a number who have may abandon the system during periods of food shortage. In effect, therefore, the general recommendation for the use of rotation systems may provide little guarantee against veld deterioration due to overstocking. Work on grazing capacity has however received considerable attention in recent years. Jones (1971) analysed the forage efficiency of grazing animals and linked this to grazing capacity, and Mentis and Duke (1976) and Mentis (1976a) estimated the grazing capacity of natural veld in Natal for large wild herbivores. Bransby and Tainton (1979) proposed a method for the determination of long term optimum utilization intensities. However, much of the recent work has centered more specifically on two central issues. The first, involving the determination of appropriate stocking rates for the maintenance of veld condition, has been reported on by Foran et al (1978), Tainton et al (1978), Tainton and Edwards (1979) and Tainton et al (1980), while the second, based on the adoption of stocking rates which would ensure economic viability in the short term, has been discussed by Booyesen (1975), Booyesen et al (1975), Danckwerts and van Rooyen (1980), Edwards (1980), Danckwerts (1982) and Mentis (1983).

(v) Grazing trials

Generalized grazing trials have been attempted at a number of Research Stations throughout the grassland biome but have seldom produced clearcut results (Gammon, 1978a). Used as a research tool they are generally too inflexible to achieve the objective of providing sound information on the most suitable grazing system to use and in any event they usually involve the simultaneous variation of a large number of components of the system so that the results are difficult to interpret. Such general trials are useful only to test systems developed from a thorough knowledge of the component variables which go to make up a system, and here they also play an important extension role.

The use of grazing systems in grassland research is, however, justified when they are designed to examine specific components of a grazing system. Here all variables not being investigated are kept constant. However, few trials have been undertaken in this way. Rethman and Booyesen (1966) reported specifically on management designed to encourage seeding in Themeda triandra, Tainton et al (1977) on the effects of different combinations of presence and absence in the grazing rotation, Vorster and Visagie (1980) compared grazing systems with different camp

numbers at different stocking rates on animal performance and veld condition and Skinner (1976) compared the response of veld to grazing by angora goats and merino sheep.

4. Invasion of undesirable plants

Yet another area of major concern has been the invasion of grassveld by a number of relatively poor forage producing or woody species and isolated attempts have been made to eliminate existing populations of such species. Tainton (1977), Walker et al (1981) and Goodman (1979) have discussed the competitive relationships between grass and bush species. The general problem of *Acacia* invasion has been outlined by van der Schijff (1964), Scott (1967), Trollope (1977) and Densham (1977) and du Toit (1968) has reported on the effect of a stand of *Acacia karroo* on the herbaceous layer. Eradication has largely been attempted by using fire (Donaldson, 1966; 1967; Trollope, 1980) or herbicides (du Toit and Nel, 1973; Sousa de Almeida, 1974). The combined use of fire and browsing animals has been recommended by Trollope (1980), and Donaldson (1978) has reported on the response of the grass component to the eradication of bush species.

The control of macchia which has invaded parts of the mountain grasslands of the eastern Cape Province has been successfully implemented with controlled burning (Trollope and Booyesen, 1971; Trollope, 1973), resulting in an improvement of the herbaceous layer (Downing et al, 1978). The same mountain grasslands are subject to replacement by *Nasella*, and le Roux and Howe (1983) have discussed methods of replacing *Nasella* with potentially productive pasture grasses and legumes.

Other problem species, often of local occurrence, in which research on eradication has been undertaken include *Senecio retrorsus* (Brynard, 1953; Hildyard, 1967; Hildyard and Booyesen, 1971); *Pachystigma pygmaem* (Coetzee, 1972); *Aristida junciformis* (Cross and Theron, 1970; Steinke et al, 1970); *Helichrysum argyrophyllum* (Story, 1952), *Stoebe vulgaris* (Cohen, 1940; van Rensburg, 1941; Smit, 1955; Hatting, 1953; Krupko and Davidson, 1961); and *Elionurus muticus* (Opperman et al, 1974; Nel, 1983; Brockett, 1983).

5. Soil conservation

The progress in planning for improved soil conservation during the 10 year period following the promulgation of the Soil Conservation Act was described in optimistic terms in 1958 (Anon., 1958) but it would now seem that the Act has in fact been largely ineffectual in substantially reducing soil erosion in South Africa. Nonetheless soil erosion has for many years been, and remains, a factor of considerable importance but research into the effects of different patterns of land-use on soil loss has been somewhat sporadic. Measurement of soil loss in large-scale grazing trials is expensive and the results are often confounded by non-uniformity of the soils, aspect or slope of the experimental sites available. Consequently, this aspect has been researched indirectly by assuming a negative relationship between the amount of soil lost and the basal and canopy cover of an area of veld. However, some direct evidence on soil loss is available (Haylett, 1960; du Plessis and Mostert, 1965; Elwell, 1972; Elwell and Stocking, 1973; 1974). Roberts (1965) has discussed the role of veld management in soil conservation and van der

Berg, Roberts and Vorster (1976) the influence of grazing in different seasons on the infiltration capacity of soils. Howell D (1976) has emphasised the role of the animal in the revegetation of problem patches of veld.

6. Game conservation and utilization

The conservation and/or utilization of game species for recreation or commercially for the production of meat, trophies, etc, has recently received considerable attention in South Africa, but this work has been undertaken largely in bushveld rather than in grassveld areas. von la Chevallerie (1970) has sketched the potential of game animals as meat producers and Bigalke (1966), Berry (1975), Walker (1976) and Mentis (1979) have discussed game ranching. Mentis and Collinson (1979) have outlined the goals which should be aimed at in wildlife reserves, and Louw (1970) the relevance of physiological adaptation as a criterion in planning production from wild ungulates. The type and abundance of the natural fauna is closely tied to the management which is applied to an area of natural vegetation. In this respect the way in which fire is used appears to be paramount, as shown by Mentis and Bigalke (1973; 1981) and Mentis and Rowe-Rowe (1979). The concepts governing the production of game from veld in South Africa have been dealt with in some detail in a series of congresses organized by the Hlabisa Soil Conservation Committee (Mentis, 1976a; 1976b; 1977a; 1979; Bourquin, 1976), and appropriate stocking rates by Mentis (1977b).

7. Veld fertilization and radical veld improvement

The response of veld to the application of fertilizers was first investigated in the Bankenveld and was given considerable impetus by initial publications by Hall et al (1937; 1940) and Hall et al (1955). Fertilizer trials followed in a number of grassveld areas eg Transvaal highveld (Weinmann, 1943b; Hall et al, 1950; 1955; Rethman and Malherbe, 1970; Altona, 1971; Wiltshire, 1972; 1973; Edwards and Nel, 1973a; 1973b), the Cymbopogon-Themeda veld of the Orange Free State (Vorster and Mostert, 1968; von Ginkel, 1969) and the Tall Grassveld of Natal (Booyesen, 1954; I'Ons, 1973). Visser (1966), Grunow et al (1970), Hyam and Penderis (1975) and Booyesen (1981) have reviewed and summarized the production response of veld in South Africa to fertilizer application while Heard (1971) has discussed the influence of application of fertilizer on animal health.

Long term trials at Pietermaritzburg have thrown considerable light on the possibility of achieving improved production economically in this way (Booyesen, 1954; Anon., 1951-1982). Visser (1959), Grunow et al (1970) and Rethman and Malherbe (1972) have also reported on the economic feasibility of fertilizing veld. In general, however, it is accepted that there is a very real danger, in fertilizing veld, of inducing the dominance of unpalatable pioneer grasses. This pattern is typical of fertilized veld.

Where the driving variables are such that practical manipulations (eg the introduction of potentially more productive species or the addition of plant nutrients) are capable of improving the level of primary production, veld may be reinforced with or replaced by more productive pasture species. Research into the areas suited to such manipulations and the means whereby they can be achieved has received considerable

attention in recent years. Edwards et al (1980) have outlined the environmental modifications required to achieve these objectives. The prospects for such modification in South Africa have been dealt with by Edwards (1966; 1972b), Booysen (1970; 1972; 1978; 1980), Theron et al (1974), Theron (1975) and Edwards and Booysen (1972), and the techniques by which species modifications can be made by Scott (1937), Graven et al (1968), Graven and Theron (1970), van Rensburg (1971), Rethman and Beukes (1973), Theron et al (1975), Hyam and Penderis (1977) and Edwards (1978). Edwards et al (1972) have reported on the effects of competition from the existing veld grasses on the success of establishment of overseeded species. Edwards (1983) has reported on the extremely disappointing results achieved with reinforcement trials, which is typical also of many large scale programmes undertaken by farmers. In contrast, complete replacement of veld, in association with the application of high levels of fertilizer and where possible, irrigation, has proved to provide a big boost to production. In this respect, the vlei areas often have an especially high productive potential (Theron, 1970).

Having achieved the reinforcement of or replacement of the natural community by a sward comprising potentially more productive species, the continued addition of plant nutrients is essential if high levels of production are to be maintained. The work undertaken in this field will not be covered in this review.

As an alternative to the replacement of veld with improved pasture, much veld continues to be ploughed for arable crops and used for afforestation. This aspect also, will not be discussed.

8. Catchment management

Veld management aimed specifically at areas designated as primary water catchment areas has been researched at the Cathedral Peak Forestry Research Station, but direct results relating veld management to the yield and quality of water derived from catchment areas is sparse. Wicht (1959), Nanni (1956; 1960), Ackerman (1976) and Bosch and Hewlett (1982) have reported on this aspect and Everson (personal communication, 1983) is currently modelling water yield and sediment loads from veld which has been subjected to different burning treatments in the past. The results of this analysis are likely to prove invaluable in the planning of management strategies in grassland catchments. To a large extent, however, management in catchment areas is based on results derived from management research undertaken at the agriculturally orientated research stations.

Soil erosion from areas once bared has always been a problem in these high-altitude catchment areas because bared areas recover only very slowly. However, Haigh (1973) has described methods of regrassing such areas, and so the technology to overcome this problem is currently available.

6. REFERENCES

- ACKERMANN D P 1976. Control of water catchments by the Department of Forestry. South African Forestry Journal 98, 24-27.
- ACOCKS J P H 1975. Veld types of South Africa. Botanical Survey of South Africa Memoirs 28, 1-192.
- ACOCKS J P H 1964. Karroo vegetation in relation to the development of deserts. In: Davis D H S (ed) Ecological studies in Southern Africa. Junk, The Hague. pp 100-112.
- ACOCKS J P H 1966. Non-selective grazing as a means of veld reclamation. Proceedings of the Grassland Society of Southern Africa 1, 33-39.
- ACOCKS J P H 1979. The flora that matched the fauna. Bothalia 12,4: 673-709.
- ADAMSON R S 1938. The vegetation of South Africa. The British Empire Vegetation Committee, London. 235 pp.
- AITKEN R D 1921. The plant succession in a type of midland tree veld in Natal. South African Journal of Science 18, 233-243.
- AITKEN R D 1922. The effects of slope exposure on climate and vegetation of a hill near Pietermaritzburg. South African Journal of Science 79, 207-217.
- AITKEN R D and GALE G W 1921. Botanical survey of Natal and Zululand. A reconnaissance trip through North-Eastern Zululand. Botanical Survey of South Africa Memoirs 2, 1-19.
- ALLSOP R J 1945. Notes on the ecology of associated grassveld plants of Pietermaritzburg, South Africa. MSc thesis, University of South Africa.
- ALTONA R E 1971. The increase in production of artificial and natural pastures as well as fodder crops by fertilizers. The Fertilizer Society of South Africa Journal 1, 23-28.
- ALTONA R E 1972. The influence of soil fertility on secondary succession. Proceedings of the Grassland Society of southern Africa 7, 20-22.
- AMORY A M 1983. The effects of nitrogen infiltration into plant tissue on the metabolism of carbon, with special reference to Themeda triandra Forsk. PhD Thesis, University of the Witwatersrand.
- AMORY A M and CRESSWELL C F 1980. Inorganic nitrogen and enhanced CO₂ evolution and formate production in the light in C₄ photosynthetic grasses. In: Proceedings of the Fifth International Congress on Photosynthesis. Greece.
- AMORY A M and CRESSWELL C F 1981. A stimulation of an alternative photorespiratory CO₂ pathway by nitrogen in Themeda triandra - a possible explanation for its sensitivity to nitrogen. Proceedings of the Grassland Society of Southern Africa 16: 145-149.

- ANON 1923. Final report of the Drought Investigation Commission. Cape Times Ltd., Government Printers, October 1923.
- ANON 1933. Judicious veld burning. Farming in South Africa 8, 247-248.
- ANON 1938. Pasture research progress report No 1. S.A. Dept. Agric. Govt. Printer, Pretoria.
- ANON 1940. Pasture research progress report No. 2. S A. Dept. Agric. Govt. Printer, Pretoria.
- ANON 1951. Pasture research progress report No. 3. S.A. Dept. Agric. Govt. Printer, Pretoria.
- ANON 1951-1982. Reports of the Dept. of Pasture Science, University of Natal, Pietermaritburg.
- ANON 1956. Veld burning: devastation or a blessing - the opinion of the experts. Farming in South Africa 32(5), 14-20.
- ANON 1957. Climate of South Africa. IV. Rainfall maps. Government Printer, Pretoria. 32 pp.
- ANON 1958. Progress in terms of the soil conservation act during the first ten years of its operation. Division of soil conservation and extension, Pretoria. 73 pp.
- ANON 1959. Burn veld judiciously. Farming in South Africa 35(4), 5 and 13.
- ANON 1960. Climate of South Africa (V). District rainfall. Government Printer and Weather Bureau, Pretoria. 51 pp.
- ANON 1968. Incalculable damage through untimely veld fires. Farming in South Africa 44(3), 5.
- ANON 1969. Proceedings of the Veld Management Conference, Bulawayo.
- ANON 1970. The Drakensberg Catchment Reserve: a guide plan for optimum utilization of natural resources. Department of Planning, South Africa. 94 pp.
- ANON 1972a. A burning question. Farming in South Africa 48(5) 486-487.
- ANON 1972b. Practical veld management: sourveld and sweetveld. Golden Fleece 11, 1-4.
- ANON 1975b. A description of the Savanna Ecosystem Project, Nylsvley, South Africa. South African National Scientific Programmes Report No 1. CSIR, Pretoria.
- ANON 1976a. Climate of South Africa. VIII. General survey. Government Printer and Weather Bureau, Pretoria. 330 pp.

- ANON 1976b. Soil loss estimator for Southern Africa. Research Bulletin 7. Department of Agricultural Technical Services, Pietermaritzburg. 64 pp.
- ANON 1978a. Nylsvley - a South African Savanna Ecosystems Project: objectives, organization and research programme. South African National Scientific Programmes Report No 27. CSIR, Pretoria.
- ANON 1978b. The agricultural potential of the Ciskei. Amended report (Co. ord. M.C. Laker), Faculty of Agriculture, University of Fort Hare.
- ANON 1980. Veld management. In: Lesch S F et al. Natal beef guide. Department of Agriculture and Fisheries, Natal. pp 125-130.
- ARIOVICH D, VINOGRAD P and CRESSWELL C F 1981. The regulation of starch accumulation in Panicum maximum Jacq. by nitrogen. Proceedings of the Grassland Society of Southern Africa 16: 151-154.
- AUCAMP A J 1976. The role of the browser in the bushveld of the Eastern Cape. Proceedings of the Grassland Society of southern Africa 11, 135-138.
- BAILEY, A W and MAPPLEDORAM B D 1983. Effect of spring grazing on yield of three grasses of the Highland Sourveld of Natal. Proceedings of the Grassland Society of southern Africa 18: 95-100.
- BANKS C H 1961. The hydrological effects of riparian and adjoining vegetation. Forestry in South Africa 1, 31-45.
- BARNABAS AD and STEINKE T D 1975. An autoradiographic study of the translocation of ¹⁴C-labelled assimilates in Eragrostis curvula (Schrad) Nees at different stages of vegetative growth. Journal of South African Botany 41(1), 17-27.
- BARNES D L 1960a. Growth and management studies on Sabi Panicum and Star grass. Part I. Rhodesian Agricultural Journal 57: 399-411.
- BARNES D L 1960b. Growth and management studies on Sabi Panicum and Star grass. Part II. Rhodesian Agricultural Journal 57: 451-457.
- BARNES D L 1961. Residual effects of cutting-frequency and fertilizing with nitrogen on root and shoot growth and the available carbohydrate and nitrogen content of the roots of Sabi Panicum. Rhodesian Agricultural Journal 58: 365-369.
- BARNES D L 1972. Defoliation effects on perennial grasses - continuing confusion. Proceedings of the Grassland Society of Southern Africa 7, 138-145.
- BARNES D L and HAVA K 1963. Effects of cutting on seasonal change in the roots of Sabi Panicum (Panicum maximum Jacq). Rhodesian Journal of Agricultural Research 1: 107-110.
- BARNES D L, ODENDAAL J J and BEUKES B H 1982. Use of the dry-weight-rank method of botanical analysis in the eastern Transvaal Highveld. Proceedings of the Grassland Society of southern Africa 17: 79-82.

- BARTHOLOMEW P E 1968. A study of growth in Eragrostis curvula. MSc thesis, University of Natal.
- BARTHOLOMEW P E and BOOYSEN P de V 1969. The influence of clipping frequency on reserve carbohydrates and regrowth of Eragrostis curvula. Proceedings of the Grassland Society of southern Africa 4, 35-43.
- BAYER A W 1933. The relation of vegetation to soil erosion in the Natal thornveld. South African Journal of Science 30, 280-287.
- BAYER A W 1938. An account of the plant ecology of the coast belt and midlands of Zululand. Annals of the Natal Museum 8(3), 371-455.
- BAYER A W 1953. Notes on the vegetation of Natal. Natal Society for the preservation of Wildlife and Natural Resorts Journal 2, 19-21.
- BAYER A W 1955. The ecology of grasslands. In: Meredith D (ed). The grasses and pastures of South Africa. CNA, Johannesburg. pp 539-550.
- BEARD J S 1962. Rainfall interception by grass. South African Forestry Journal 42, 12-15.
- BERRY M P S 1975. Game ranching in Natal. Journal of South African Wildlife Management Association 5(1) 33-37.
- BEWS J W 1912. The vegetation of Natal. Annals of the Natal Museum 2, 253-331.
- BEWS J W 1913. An ecological survey of the midlands of Natal, with special reference to the Pietermaritzburg district. Annals of the Natal Museum 2, 485-545.
- BEWS J W 1916a. An account of the chief types of vegetation in South Africa with notes on the plant succession. Journal of Ecology 1, 29-59.
- BEWS J W 1916b. Growth-forms of Natal plants. Transactions of the Royal Society of South Africa, 605.
- BEWS J W 1917. The plant ecology of the Drakensberg range. Annals of the Natal Museum 3, 511-565.
- BEWS J W 1918a. Plant succession in the thornveld. South African Journal of Science 14, 153-171.
- BEWS J W 1918b. The grasses and grasslands of South Africa. Dawies & Sons, Pietermaritzburg, 161 pp.
- BEWS J W 1920. The plant ecology of the coast belt of Natal. Annals of the Natal Museum 4, 367-469.
- BEWS J W 1925. Plant forms and their evolution in South Africa. Longmans, London. 199 pp.
- BEWS J W 1931. Researches on the vegetation of Natal (I, II and III). South African Journal of Science 28, 158-179.

- BIGALKE R C 1966. Some thoughts on game farming. Proceedings of the Grassland Society of Southern Africa 1, 95-102.
- BIGALKE R C 1976. Terrestrial faunal resources of southern Africa. In: Baker G (ed) Resources of southern Africa - today, tomorrow. Associated Scientific and Technical Societies of South Africa, pp 161-173.
- BOOYSEN P de V 1954. An investigation into the effects of certain fertilizers on quality and yields of herbage and botanical composition of the veld. MSc Agricultural thesis, University of Natal.
- BOOYSEN P de V 1956. In the grass veld management it is the principles that count, not the systems. Farming in South Africa 32(7), 34-40.
- BOOYSEN P de V 1966. A physiological approach to research in pasture utilization. Proceedings of the Grassland Society of Southern Africa 1, 77-85.
- BOOYSEN P de V 1967. Grazing and grazing management terminology in southern Africa. Proceedings of the Grassland Society of Southern Africa 2, 45-57.
- BOOYSEN P de V 1969. An analysis of the fundamentals of grazing management systems. Proceedings of the Grassland Society of Southern Africa 4, 84-91.
- BOOYSEN P de V 1970. The pasture prospect in the humid grasslands of South Africa. Proceedings of the New Zealand Grassland Association 32, 50-60.
- BOOYSEN P de V 1972. Pastoral productivity and intensification. Proceedings of the Grassland Society of Southern Africa 7, 51-55.
- BOOYSEN P de V 1975. Economic optimisation of stocking rate and grazing management. Proc. European Grassld. Fed. 6th meeting. Madrid: 243-245.
- BOOYSEN P de V 1978. Range improvement opportunities. Proceedings of the Grassland Society of Southern Africa 1, 14-16.
- BOOYSEN P de V 1980. Pasture improvement possibilities in effective animal production systems. South African Journal of Animal Science 10, 293-298.
- BOOYSEN P de V 1981. Radical veld improvement. In: Veld and pasture management in South Africa. Ed N M Tainton. Shuter and Shooter, Pietermaritzburg in association with Natal University Press: 57-90.
- BOOYSEN P de V, KLUG J R and YORK B S 1974. Number of camps for rotational grazing of veld. Proceedings of the Grassland Society of Southern Africa 9, 145-148.
- BOOYSEN P de V and TAINTON N M 1978. Grassland management: principles and practice in South Africa. Proceedings of the International Rangeland Congress 1, 551-554.
- BOOYSEN P de V and TAINTON N M 1984. Ecological effects of fire in South African ecosystems. Ecol. Studies 48. Springer.

BOOYSEN P de V, TAINTON N M and FORAN B D 1975. An economic solution to the grazing management dilemma. Proceedings of the Grassland Society of Southern Africa 10, 77-83.

BOOYSEN P de V, TAINTON N M and SCOTT J D 1963. Shoot apex development in grasses and its importance in grassland management. Herbage Abstracts 33, 209-213.

BOSCH O J H 1974. Die wisselwerking tussen die habitat en 'n aantal grasgemeenskappe in die suidoostelike Oranje-Vrystaat. DSc thesis, Potchefstroom University for CHE.

BOSCH O J H 1977. Ordering van 'n aantal grondprofile van die Sterkspruitvorm: 'n Basis vir die verklaring van floristiese verskille tussen sommige weivelddtipes wat op gronde van die Sterkspruitvorm voorkom. Agrochemophysica 9: 21-52.

BOSCH O J H 1978. Vergelyking tussen die plantegroei en habitatte van die gronde van die Estcourt- en Sterkspruit- vorms in die suidoostelike Oranje-Vrystaat. Bothalia 12: 499-511.

BOSCH J M 1980. 'n Ontleding van die hidrologiese eksperimente in die Cathedral Peak omvangsgebied. MSc thesis, University of Stellenbosch.

BOSCH J M and HEWLETT J D 1982. A review of catchment experiments to determine the effect of vegetation changes on water yield and evapotranspiration. Journal of Hydrology 55: 3-23.

BOTHA J P 1945. The burning of veld. Farming in South Africa 20, 404.

BOURQUIN O 1976. Control of game movement. Proceedings of the Veld and Game symposium. Hlabisa Soil Cons. Committee: 28-38.

BOURQUIN O and CHANNING A 1980. Herpetofauna of the Natal Drakensberg: an annotated checklist. The Lammergeyer 30, 1-20.

BOWEN W W 1933. African bird distribution in relation to temperature and rainfall. Ecology 14(3), 247-271.

BRANSBY D I 1975. A simple instrument for estimating pasture yield in situ. MSc thesis, University of Missouri.

BRANSBY D I, BOOYSEN P de V and TAINTON N M 1977. The evaluation of pastures and grazing management in terms of livestock production. Proceedings of the Grassland Society of Southern Africa 10, 77-82.

BRANSBY D I and TAINTON N M 1979. The proposed method for determining long term optimum utilization intensities of pastures and veld. Proceedings of the Grassland Society of Southern Africa 10, 49-52.

BREDENKAMP G J 1975. Plant communities of the Suikerbosrand Nature Reserve, Transvaal. South African Journal of Science 71, 30-31.

BREDENKAMP G J 1977. The gasses of the Suikerbosrand Nature Reserve: their habitat preferences and synecological significance. Proceedings of the Grassland Society of Southern Africa 12, 135-139.

BREDENKAMP G J and THERON G K 1976. Vegetation units for management of the grasslands of the Suikerbosrand Nature Reserve. South African Journal of Wild Reserves 6, 113.

BREDON R M, LYLE A D and SWART C 1970. The use of oesophageal fistulated cattle on summer veld in East Griqualand. Proceedings of the Grassland Society of Southern Africa 9, 163-167.

BREEN C M 1971. An account of the plant ecology of the dune forest at Lake Sibayi. Transactions of the Royal Society of South Africa 39(3), 223-234.

BRETT P G C 1941. The assimilation and respiration rates of some Natal grasses. South African Journal of Science 38, 158-171.

BRIDGENS A B 1968. Aspects of shoot apex morphogenesis, development and behaviour in grasses, with reference to the utilization and management of natural grassland. Technical Communication, Department of Agricultural and Technical Services 67, 1-44.

BROCKETT G M 1983 The effect of defoliation on the persistence of Elionurus muticus (Spreng) Kunth in the Highland Sourveld of Natal. Proceedings of the Grassland Society of Southern Africa 18: 81-83.

BROMBERGER N and LEA J D (eds) 1983. Rural studies in KwaZulu. Proc. symposium Univ. of Natal Subsistence Agric. study group/Development studies res. group. 166 pp.

BRYNARD A M 1953. 'n Fisiologies - ekologiese studie van Senecio retrorsus, DC. MSc thesis, Potchefstroom University for CHE.

BURGER S J, GRUNOW J O and RABIE J W 1975. Die reaksie van Antheophora pubescens nees op verskillende intensiteite en frekwensies van ontblaring. Proceedings of the Grassland Society of Southern Africa 10, 29-34.

BURTT-DAVY J and CRAWLEY V C 1909. The families, genera and species of Pteridophyta of the Transvaal province. South African Journal of Science 6, 455-482.

CAMPBELL G G 1969. A review of scientific investigations in the Tongaland area of Northern Natal. Transactions of the Royal Society of South Africa 38(4), 305-316.

CAMPBELL G K 1966. Woody plants of the Kenneth Steinbank Nature Reserve, Durban. The Lammergeyer 6, 47-62.

CAOTIN W G H 1958. The hodotermitid harvester termites of South Africa. Department of Agricultural Science Bulletin, 375 pp.

- CASS A 1978. The effect of burning and mowing on soil physical properties. Unpublished report. Department of Soil Science and Agrometeorology, University of Natal, Pietermaritzburg.
- CLANCEY P A 1964. The birds of Natal and Zululand. Oliver and Boyd, London, 511 pp.
- CLANCEY P A 1967. Game birds of southern Africa. Purnell and Sons, Cape Town, pp 224.
- CLARK D H 1956. Studies on growth and development of certain veld grasses. MSc thesis. University of Natal.
- CLEMENCE B S E and SCHULZE R E 1982. An assessment of temperature based equations for estimating daily crop water loss to the atmosphere in South Africa. Crop Production 11, 21-25.
- COETZEE G 1972. Control of Pachystigma pygmaeum with herbicide. Proceedings of the Grassland Society of Southern Africa 7, 28-31.
- COETZEE G 1975. Grazing of Cymbopogon - Themeda veld in the dormant period. Proceedings of the Grassland Society of Southern Africa 10, 147-150.
- COETZEE P J S 1942. Fire and veld management. Veld burning as an agent in the "Ngongoni" sourveld. Farming in South Africa 17, 107-116 and 131.
- COETZEE J A, PAGE M I and MEREDITH D 1946. Root studies in Highveld grassland communities. South African Journal of Science 42, 105-118.
- COHEN C 1940. Stoebe vulgaris, a study of an ecological problem. Journal of South African Botany 6, 79-110.
- COLLINSON R F H 1979. Production economics of impala. In: Proceedings of the Beef and Game Management Symposium, Hlabisa Soil Conservation Committee, 90-103.
- COOK L 1939. A contribution to our information on grass burning. South African Journal of Science 36, 270-282.
- COOKE H B S 1964. The Pleistocene environment in southern Africa. In: Davies D H S (ed) Ecological studies in southern Africa. Junk, the Hague, pp 1-23.
- COUTTS J R H 1945. Effect of veld burning on the base exchange capacity of a soil. South African Journal of Science 41, 218-224.
- CRESWELL C and NELSON H 1971. The effect of Boron on the breaking of dormancy and germination of Rooigras, Themeda triandra Forsk. South African Journal of Science 67, 471-474.
- CRESWELL C F and NELSON H 1972. The effect of micronutrients and gibberellic acid on the germination and metabolism of seedlings of Themeda triandra Forsk. Proceedings of the Grassland Society of southern Africa 7, 133-137.

CROSS G W and THERON E P 1970. Effectiveness of paraquat on the Ngongoni veld of the Natal mistbelt. Proceedings of the Grassland Society of Southern Africa 5, 101-105.

DAINES T 1980. The use of grazing patterns in the management of Dohne sourveld. Proceedings of the Grassland Society of Southern Africa 15, 185-188.

DANCKWERTS J E 1979. Recession of the grassland formation in South Africa. Unpublished report.

DANKWERTS J E 1982. The grazing capacity of sweetveld. 2. A model to estimate the grazing capacity in the thornveld of the Eastern Cape. Proceedings of the Grassland Society of southern Africa 17, 94-98.

DANCKWERTS J E, AUCAMP A J and BARNARD H J 1983. Herbaceous species preference by cattle in the False Thornveld of the eastern Cape. Proceedings of the Grassland Society of Southern Africa 18, 89-94.

DANCKWERTS J E and TROLLOPE W S W 1980. Assessment of the disc pasture meter on natural veld in the false thornveld of the Eastern Province. Proceedings of the Grassland Society of Southern Africa 15, 47-52.

DANCKWERTS J E and VAN ROOYEN C J 1980. Maximum profitability as a criterion for optimisation of utilization intensity. Proceedings of the Grassland Society of Southern Africa 15, 53-57.

DAVIDSON R L 1942. Some observations on the relationships between vegetation and insect populations. South African Journal of Science 39, 139-146.

DAVIDSON R L 1951. Further analysis of a veld burning experiment at Bethal. Annual Report for 1951 of the Frankenwald Field Research Station, 39-46.

DAVIDSON R L 1952. Herbage yields from a seasonal burn experiment at Bethal. Annual Report for 1952 of the Frankenwald Field Research Station. University of the Witwatersrand, Johannesburg, 32-34.

DAVIDSON R L 1962. The influence of edaphic factors on the species composition of early stages of the subsere. Journal of Ecology 50, 401-110.

DAVIDSON R L 1964. An experimental study of succession in the Transvaal Highveld. In: David D H S (ed) Ecological studies in southern Africa. Junk, The Hague, pp 113-125.

DAVIDSON R L 1965. Management of sown and natural lovegrass. Journal of Range Management 18, 214-218.

DE JAGER J M 1971. Model for expressing leaf photosynthesis in terms of weather variables. Proceedings of the Grassland Society of southern Africa 6, 144-151.

DE JAGER J M and SCHULZE R E 1977. The broad geographic distribution in Natal of climatological factors important to agricultural planning. *Agrochemophysica* 9, 81-91.

DE JAGER L A and JOUBERT D M 1968. Benutting van natuurlike weiding in die Transvaalse Bankenveld deur Merino hamels. *Tydskrif vir Natuurwetenskappe* 1, 1-26.

DE JAGER J M, OPPERMAN D P J and BOOYSEN J 1980. Produksie van natuurlike grasveld in die sentrale Oranje-Vrystaat in verhouding tot klimaat. *Proceedings of the Grassland Society of Southern Africa* 15, 65-68.

DENNY R P and BARNES D L 1977. Trials of multi-paddock grazing systems on veld. 3. A comparison of six grazing procedures at two stocking rates. *Rhodesian Journal of Agricultural Research* 15, 129-142.

DENNY R P , BARNES D L and KENNAN T C D 1977. Trials of multi-paddock grazing systems on veld. 1. An exploratory trial of systems involving twelve paddocks and one herd. *Rhodesian Journal of Agricultural Research* 15, 11-24.

DENNY R P and STEYN J S H 1977. Trials of multi-paddock grazing systems on veld. 2. A comparison of a 16-paddocks-to-one-herd system with a four-paddock-to-one-herd system using breeding cows. *Rhodesian Journal of Agricultural Research* 15, 119-128.

DENSHAM D 1977. Practical bush control in a game reserve. *Proceedings of the symposium on Veld and Bush Management for Beef and Game production. Proceedings of the Hlabisa Soil Conservation Committee*, 72-86.

DIATZ J 1953. A further report on the seasonal burning experiment at Bethal. *Annual Report for 1953 of the Frankenwald Field Research Station. University of the Witwatersrand, Johannesburg.*

DIATZ J 1954. Available CHO reserves in the roots of Themeda triandra from a seasonal burn experiment at Bethal. *Annual Report for 1954 of the Frankenwald Field Research Station.* 27-29.

DILLON R F 1980. Some effects of fire in the tall grassveld of Natal. *MSc Agricultural thesis, University of Natal, Pietermaritzburg.*

DONALDSON C H 1966. Control of Blackthorn in the Molopo area with special reference to fire. *Proceedings of the Grassland Society of southern Africa* 1, 57-62.

DONALDSON C H 1967. The immediate effects of the 1964/66 drought on the vegetation of specific study areas in the Vryburg district. *Proceedings of the Grassland Society of southern Africa* 2, 137-141.

DONALDSON C H 1967. Further findings on the effects of fire on Blackthorn. *Proceedings of the Grassland Society of southern Africa* 2, 59-61.

DONALDSON C H 1978. Evaluation of Cenchrus ciliaris. II. A comparison of Bushveld combined with Cenchrus pastures. *Proceedings of the Grassland Society of Southern Africa* 13, 45-48.

- DONALDSON C H, KELK D M and WEST K N 1972. Antheophora pubescens Nees. Proceedings of the Grassland Society of Southern Africa 7, 112-116.
- DOWNING B H 1966. The plant ecology of Tabamhlope Vlei. MSc thesis, University of Natal.
- DOWNING B H 1968. Notes on the ecology of Natal Highland sourveld vleis. Proceedings of the Grassland Society of Southern Africa 3, 131-134.
- DOWNING B H 1970. Some aspects of vlei plant ecology in the Natal Highland sourveld. South African Institute of Agricultural Extension.
- DOWNING B H, ROBINSON E R, TROLLOPE W S W and MORRIS J W 1978. Influence of Macchia eradication techniques on botanical composition of grasses in the Dohne sourveld of the Amatole mountains. Proceedings of the Grassland Society of Southern Africa 13, 111-115.
- DOWNING B H and MARSHALL D J 1980. Complementary dominance of Themeda triandra and Panicum maximum examined through shoot production. Proceedings of the Grassland Society of Southern Africa 15, 167-171.
- DOWNING D H and MARSHALL D J 1983. Burning and grazing of a Themeda grassland: Estimates of phytomass and root element concentrations. Proceedings of the Grassland Society of Southern Africa 18, 155-158.
- DREWES R H 1979. The response of veld to different winter removal treatments. MSc thesis, University of Natal.
- DREWES R H and TAINTON N M 1981. The effect of different winter and early spring removal treatments on Themeda triandra in the Tall Grassveld of Natal. Proceedings of the Grassland Society of Southern Africa 16, 139-143.
- DU PLESSIS M C F and MOSTERT J W C 1965. Afloop en grondverliese by die Landbounavorsingsinstituut, Glen. Suid Afrikaanse Tydskrif vir Landbouwetenskap 8, 1051-1061.
- DU TOIT A L 1948. The Geology of South Africa. Oliver and Boyd, Edinburgh and London, 611 pp.
- DU TOIT J 1972. Morfologiese en produksiestudies op Cenchrus ciliaris L. MSc Agricultural thesis, University of Pretoria.
- DU TOIT J, RABIE J W and GRUNOW J O 1973. Voedings- en produksie studies van Cenchrus ciliaris LW Molopo. Proceedings of the Grassland Society of Southern Africa 8, 107-115.
- DU TOIT P F 1967. Bush encroachment with specific reference to Acacia karroo encroachment. Proceedings of the Grassland Society of Southern Africa 2, 119-126.
- DU TOIT P F 1968. A preliminary report on the effect of Acacia karroo competition on the composition and yield of sweet grassveld. Proceedings of the Grassland Society of Southern Africa 3, 147-149.
- DU TOIT P F 1969. Veldbeheer in die Ooskaapse suurveld. Boerdery in Suid Afrika 45(5), 17-19.

- DU TOIT P F 1972b. Acacia karroo intrusion: the effect of burning and sparing. Proceedings of the Grassland Society of Southern Africa 7, 23-27.
- DU TOIT R F 1972c. The goat in a bush-grass community. Proceedings of the Grassland Society of Southern Africa 7, 44-50.
- DU TOIT R F and INGPEN R A 1970. Some effects of winter grazing of Dohne sourveld. Proceedings of the Grassland Society of Southern Africa 5, 27-31.
- DU TOIT R F and NEL L O 1973. Chemiese beheer van Acacia karroo. Proceedings of the Grassland Society of Southern Africa 8, 29-34.
- DYER T G S 1975. The assignment of rainfall stations into homogeneous groups: an application of principal component analysis. Quarterly Journal of the Royal Meteorological Society 101, 1005-1013.
- DYER T G J and TYSON P D 1977. Estimating above and below normal rainfall periods over South Africa, 1972-2000. Journal of Applied Meteorology 16, 145-147.
- EDWARDS D 1967. A plant ecological survey of the Tugela River basin. Memoirs of the Botanical Survey of South Africa 36, 285 pp.
- EDWARDS D 1972. Botanical Survey and Agriculture. Proceedings of the Grassland Society of Southern Africa 7, 15-19.
- EDWARDS D 1974. Survey to determine the adequacy of existing conserved areas in relation to vegetation types. A preliminary report. Koedoe 17, 2-37.
- EDWARDS D 1976. Floral resources of southern Africa. In: Baker G (ed) Resources of southern Africa - Today and Tomorrow. Associated Scientific and Technical Societies of South Africa. pp 154-160.
- EDWARDS D 1984. Fire regimes in the biomes of South Africa. In: The ecological effects of fire in South African Ecosystems. Eds P de V Booyesen and N M Tainton. Ecological Studies 48. Springer, 19-37.
- EDWARDS D, DE VOS W H, HARTKOPF D, HATTINGH D J, SCHEEPERS J J and WILBY A F 1983. Monitoring of veld burns using satellite imagery. Proceedings of the Grassland Society of Southern Africa 18, 131-134.
- EDWARDS P J 1961. Studies in veld burning and mowing in the tall grass veld of Natal. MSc Agric thesis, University of Natal.
- EDWARDS P J 1965. The construction and use of light proof boxes in grassland research work. Proceedings of the 9th International Grassland Congress, 1483-1485.
- EDWARDS P J 1966. Veld replacement by improved grasslands in Natal. Proceedings of the Grassland Society of Southern Africa 1, 63-67.

- EDWARDS P J 1968. The long term effects of burning and mowing in the basal cover of two veld types in Natal. South African Journal of Agricultural Science II, 131-140.
- EDWARDS P J 1969. Veld burning in the Giant's Castle Game Reserve. The Lammergeyer 10, 64-67.
- EDWARDS P J 1969a. The evaluation of veld by animal production. Proceedings of the Grassland Society of Southern Africa 4, 99-103.
- EDWARDS P J 1972a. A system of veld classification and management planning. Technical Communication, Department of Agricultural and Technical Services 102, 12 pp.
- EDWARDS P J 1972b. The future for radical veld improvement in South Africa. Proceedings of the Grassland Society of Southern Africa 7, 61-66.
- EDWARDS P J 1973. Definitions of some pasture terms. Proceedings of the Grassland Society of Southern Africa 8, 133-135.
- EDWARDS P J 1974. Estimates of carrying capacity and production from herbage yield and grazing days. Proceedings of the Grassland Society of Southern Africa 9, 139-143.
- EDWARDS P J 1975. The effect of selective defoliation and fertilization on Cymbopogon - Themeda veld. Proceedings of the Grassland Society of Southern Africa 10, 141-146.
- EDWARDS P J 1978. Methods of veld reinforcement, their action and adaptability to various sites. Proceedings of the Grassland Society of Southern Africa 13, 71-74.
- EDWARDS P J 1980. The use of stocking rate/animal performance models in research and extension. Proceedings of the Grassland Society of Southern Africa 15, 73-77.
- EDWARDS P J 1983. A re-evaluation of veld reinforcement in Natal. Proceedings of the Grassland Society of Southern Africa 18, 64-68.
- EDWARDS P J and BOOYSEN P de V 1972. The future of radical veld improvement in South Africa. Proceedings of the Grassland Society of southern Africa 7, 61-66.
- EDWARDS P J, BOOYSEN P de V and MAPPLEDORAM B D 1972. Effects of competition on the establishment of overseeded species in the Highland sourveld of Natal. Agriplanta 4, 1-7.
- EDWARDS P J, JONES R I and TAINTON N M 1979. Aristida junciformis Trin et Pupr: a weed of the veld. Weeds 3, 25-32.
- EDWARDS P J and NEL S P 1973a. Short term effects of fertilizer and stocking rates on the Bankenveld. 1. Vegetational changes. Proceedings of the Grassland Society of Southern Africa 8, 83-88.

- EDWARDS P J and NEL S P 1973b. Short term effects of fertilizers and stocking rates on the Bankenveld. 2. Animal production. Proceedings of the Grassland Society of Southern Africa 8, 89-96.
- EDWARDS P J and SCOTNEY D M 1978. Site assessment for pasture production. Proceedings of the Grassland Society of Southern Africa 13, 65-70.
- EDWARDS P J, SCOTNEY D M, BARTHOLOMEW P E and TAINTON N M 1980. Environmental modifications for improved grassland production. Proceedings of the Grassland Society of Southern Africa 15, 19-30.
- ELLIS R P 1974. The significance of the occurrence of both kranz and non-kranz leaf anatomy in the grass species Alloteropsis semialata. South African Journal of Science 70, 169-173.
- ELLIS R P 1977. Distribution of the Kranz syndrome in the southern African Eragrostoideae and Panicoideae according to bundle sheath anatomy and cytology. Agroplantae 9, 73-110.
- ELWELL H A 1972. The influence of agricultural systems on rainfall runoff. Rhodesian Agricultural Journal, Technical Bulletin 15, 13-26.
- ELWELL H A and STOCKING M A 1973. Rainfall parameters to predict surface runoff yields and soil losses from selected field plot studies. Rhodesia Journal of Agricultural Science 11, 123-129.
- ELWELL H A and STOCKING M A 1974. Rainfall parameters and a cover model to predict runoff and soil loss from grazing trials in the Rhodesian sandveld. Proceedings of the Grassland Society of Southern Africa 9, 157-164.
- EVERSON C S 1983. Personal communication. Cathedral Peak Forest Research Station. P. O. Winterton, Natal.
- FAIR T J D and KING L C 1954. Erosional land-surfaces in the eastern marginal areas of South Africa. Transactions of the Geological Society of South Africa 57, 19-26.
- FEELY J M 1980. Did iron age man have a role in the history of Zululand's Wilderness landscapes? South African Journal of Science 76, 150-152.
- FISHER J 1954. The effects of mowing on fertilized and unfertilized veld. Annual report: Frankenwald Field Research Station, 16 pp.
- FITZSIMONS V F M 1962. Snakes of South Africa. Purnell and Sons, Cape Town, 423 pp.
- FORAN D B 1976. The development and testing of methods for assessing the condition of three grassveld types in Natal. MSc Agric thesis, University of Natal, Pietermaritzburg.
- FORAN B D, TAINTON N M and BOOYSEN P de V 1978. The development of a method for assessing veld condition in three grassveld types in Natal. Proceedings of the Grassland Society of Southern Africa 13, 27-33.

FORBES H 1921. The flora of Isipingo. South African Journal of Science 18, 348-358.

FOURIE J H and ROBERTS B R 1976. A comparative study of three veld types of the northern Cape: species evaluation and yield. Proceedings of the Grassland Society of Southern Africa 11, 79-85.

FREAN M L, ARIOVICH D and CRESSWELL C F 1980. Ontogeny of bundle sheath in C₃ and C₄ forms of Alloteropsis semialata (R.Br.) Hitchc. Proceedings of the Electron. Microsc. Soc. sth. Afr.

FREAN M, BARRET D and CRESSWELL C F 1980. Variability in leaf surface features and water efficiency utilization in C₃ and C₄ forms of Alloteropsis semialata (R Br) Hitchc. Proceedings of the Grassland Society of Southern Africa 15, 99-103.

FREAN M L and CRESSWELL C F 1981. An ontogenetic study with special reference to leaf development in C₃ and C₄ forms of Alloteropsis semialata. Proceedings of the Grassland Society of Southern Africa 16, 155-160.

GAFF D F and ELLIS R P 1974. Southern African grasses with foliage that revives after dehydration. Bothalia 11, 3: 305-308.

GALPIN E E 1908. A contribution to the knowledge of the flora of the Drakensberg. South African Journal of Science 5, 209-229.

GAMMON D M 1978a. A review of experiments comparing systems of grazing management on natural pastures. Proceedings of the Grassland Society of southern Africa 13, 75-82.

GAMMON D M 1978b. Patterns of defoliation during continuous and rotational grazing of rangeland cattle. Proceedings of the International Rangeland Congress 1, 603-605.

GAMMON D M and ROBERTS B R 1978a. Patterns of defoliation during continuous and rotational grazing of the Matopos Sandveld of Rhodesia. I. Selectivity of defoliation. Rhodesian Journal of Agricultural Research 16, 117-131.

GAMMON D M and ROBERTS B R 1978b. Patterns of defoliation during continuous and rotational grazing of the Matopos Sandveld of Rhodesia. 2. Severity of defoliation. Rhodesian Journal of Agricultural Research 16, 133-145.

GAMMON D M and ROBERTS B R 1978c. Patterns of defoliation during continuous and rotational grazing of the Matopos Sandveld of Rhodesia. 3. Frequency of defoliation. Rhodesian Journal of Agricultural Research 16, 147-164.

GANDAR M V 1980. Short-term effects of the exclusion of large mammals and insects in broad leaf savanna. South African Journal of Science 76, 29-31.

GARLAND G 1982. An appraisal of South African Research into run-off Erosion. S. A. Geographical Journal 64, 138-143.

- GIBBS RUSSELL G E 1983. Correlation between evolutionary history, flowering phenology, growth form and seral status for important veld grasses. *South African Journal of Botany* 2, 175-180.
- GILL G A 1936. Veld-burning experiments. *Farming in South Africa* 11, p 134.
- GILLILAND H B 1955. On the phenology of the veld around Johannesburg. 1. Monocotyledons. *Journal of South African Botany* 21, 77-82.
- GLOVER P E 1937. A contribution to the ecology of the highveld flora. *South African Journal of Science* 34, 224-259.
- GLOVER P E and VAN RENSBURG H J 1938. A contribution to the Highveld grasslands at Frankenwald in relation to grazing and burning. *South African Journal of Science* 35, 274-279.
- GOLDBLATT P 1978. The analysis of the flora of southern Africa: its characteristics, relationships and origins. *Ann. Missouri Bot. Garden* 65, 359-436.
- GOODMAN P S 1979. The grass/bush balance and implications for its management. *Proceedings of the Symposium on Beef and Game Management. Hlabisa Soil Conservation Committee*, 12-21.
- GRANGER J E 1976. The vegetation changes, some related factors and changes in the water balance following 20 years of fire exclusion in catchment IX. Cathedral Peak Forestry Research Station. PhD thesis, University of Natal.
- GRANGER J E and SCHULZE R E 1977. Incoming solar radiation patterns and vegetation response: Examples from the Natal Drakensburg. *Vegetatio* 35(1), 47-54.
- GRAVEN E H, BIRCH E B and MUZZELL P J 1968. Sod-seeding - a promising new development in the Eastern Cape Sourveld. *Proceedings of the Grassland Society of Southern Africa* 3, 127-129.
- GRAVEN E H and THERON E P 1970. Band placement of lime and superphosphate for ladino clover in an acid oxysol. *Proceedings of the Grassland Society of Southern Africa* 5, 106-112.
- GROSSMAN D 1982. Primary production of rangeland. Practical and interpretive problems. *Proceedings of the Grassland Society of Southern Africa* 17, 76-78.
- GROSSMAN D and CRESSWELL C F 1973. The influence of nitrogen supply in the nutrient media on the carbon dioxide compensation point (T) of C₄ photosynthetic plants. *South African Journal of Science* 69, 244-246.
- GROSSMAN D and CRESSWELL C F 1974. The influence of nitrate on the photosynthetic and photorespiratory activity of selected highveld grasses exhibiting C₄ photosynthesis. *Proceedings of the Grassland Society of Southern Africa* 9, 89-94.

GRUNOW J O 1966. Objectivity in plant classification. Proceedings of the Grassland Society of Southern Africa 1, 49-55.

GRUNOW J O 1973. Research relating to the management of South African Ecosystems. South African Journal of Science 69, 54-56.

GRUNOW J O 1980. Feed and habitat preferences among some large herbivores on African veld. Proceedings of the Grassland Society of Southern Africa 15, 141-146.

GRUNOW J O, EDWARDS D and MORRIS J W 1969. Vegetation ordination and classification. Practical implications. Proceedings of the Grassland Society of Southern Africa 4, 66-69.

GRUNOW J O and MORRIS J W 1969. Preliminary assessment of ecological status of plant species in three South African veld types. Journal of South African Botany 35, 1-12.

GRUNOW J O, PIENAAR A J and BREYTENBACH C 1970. Long term nitrogen application to veld in South Africa. Proceedings of the Grassland Society of Southern Africa 5, 79-90.

GRUNOW J O, RABIE J W and GRATTAROLA L 1977. Standing crop dry matter accumulation and quality patterns of certain subtropical pasture species. Proceedings of the Grassland Society of Southern Africa 12, 37-44.

HACKLAND N G E and JONES R I 1980. Predicting seasonal production of Eragrostis curvula. Proceedings of the Grassland Society of Southern Africa 15, 85-88.

HAIGH H 1973. Grazing eroded areas in the Drakensberg. Forestry in South Africa 14, 31-33.

HALL A V, DE WINTER M, DE WINTER B and VAN OOSTERHOUT S A M 1980. Threatened plants of southern Africa. South African National Scientific Programmes, CSIR, Report No 45, 244 pp.

HALL M 1984. Man's historical and traditional use of fire in southern Africa. In: The ecological effects of fire in southern Africa. Eds P de V Booysen and N M Tainton, Ecological Studies 48. Springer, 39-52.

HALL T D 1931. Intensive grazing on veld. South African Journal of Science 28, 202-204.

HALL T D 1934. South African pastures. Retrospective and prospective. South African Journal of Science 31, 59-97.

HALL T D, MEREDITH D and ALTONA R E 1950. Production from grassland in South Africa. Empire Journal of Experimental Agriculture 18, 8-18.

HALL T D, MEREDITH D and ALTONA R E 1955. The role of fertilizers in pasture management. In: Meredith D (ed) The grasses and pastures of South Africa. CNA, Johannesburg, pp 637-652.

HALL T D, MEREDITH D and MURRAY S M 1937. The productivity of fertilized natural Highveld pastures. South African Journal of Science 34, 275-285.

HALL T D, MEREDITH D and MURRAY S M 1940. Fertilizing natural veld and its effects on sward, chemical composition, carrying capacity and beef production. South African Journal of Science 37, 111-129.

HARMSE H J VON M 1978. Schematic soil map of southern Africa. In: Werger M J A (ed) Biogeography and Ecology in Southern Africa. Junk, The Hague, pp 73-75.

HARMSE H J VON M and GROBLER J H 1966. Grondstreke in die Hoëveldstreek. Tegniese Mededeling 55. Gov. Printer, Pretoria, 38 pp.

HATTINGH E R 1953. Observations on the ecology of Stoebe vulgaris Levyns. Empire Journal of Experimental Agriculture 21, 309-313.

HAYLETT D G 1960. Run-off and soil erosion studies at Pretoria. South African Journal of Agricultural Science 3, 379-394.

HEARD C A H 1971. The influence of pasture fertilization on animal health. Proceedings of the Grassland Society of Southern Africa 6, 134-143.

HENCKEL P A 1964. Physiology of plants under drought. Annual Review of Plant Physiology 15, 363-386.

HENRICI M 1927. Physiological plant studies in South Africa. Part I and II. Report of Veterinary Research 11 and 12, 619-702.

HENRICI M 1930a. Mineral and feeding stuff analyses of grasses of the Eastern Transvaal Highveld. Report of Veterinary Research 16, 421-434.

HENRICI M 1930b. The phosphorus content of grasses in the Eastern Transvaal. Report of Veterinary Research 16, 435-499.

HENSLEY M and DE JAGER J M 1982. Profile plant available water: estimations and importance for irrigation scheduling. Workshop on agronomic aspects of irrigation. Coordinating Committee for Irrigation Research, Pretoria, 37 pp.

HERBST S N and ROBERTS B R 1974. Quantitative ecological relationships in the Alpine grassland of Lesotho. Proceedings of the Grassland Society of Southern Africa 9, 61-66.

HEWITT J 1923. Remarks on the distribution of animals in South Africa. South African Journal of Science 20, 96-123.

HILDYARD P 1960. Uniform utilization of sourveld. Farming in South Africa 36(4), p 33-34.

HILDYARD P 1967 A study of shoot growth and development on Senecio retrorsus D.C. PhD thesis, Department of Pasture Science, University of Natal.

HILDYARD P 1970. The utilization of certain native pastures composed of grasses of varying palatability. Proceedings of the 6th International Grassland Congress, pp 41-45.

HILDYARD P and BOOYSEN P de V 1971. The influence of sward competition on shoot growth and development in Senecio retrorsus D.C. Proceedings of the Grassland Society of Southern Africa 6, 39-43.

HOFMEYER J M 1970. A review of the food preferences and feeding habits of some indigenous herbivores in the Egyptian Faunal Region and some studies of animal-plant relationships. Proceedings of the South African Society of Animal Production 9, 89-99.

HOWELL L N 1976. The development of multi-camp systems on a farm in the southern Orange Free State. Proceedings of the Grassland Society of Southern Africa 11, 53-57.

HOWELL D 1976. Observation on the role of grazing animals in revegetating problem patches of veld. Proceedings of the Grassland Society of Southern Africa 11, 59-63.

HUNTLEY B J and MORRIS J W 1978. Savanna Ecosystem Project. Phase I summary and phase II progress. South African National Scientific Programmes Report No.29.

HYAM G F S and PENDERIS A H 1975. Nitrogen fertilization of pastures and veld. Fertilizer Society of South African Journal 21, 81-82.

HYAM G F S and PENDERIS A H 1977. Techniques for fertilizing, oversowing and sod seeding veld. Proceedings of the Grassland Society of Southern Africa 12, 99-101.

I'ONS J H 1960. Studies in veld burning. MSc thesis, University of Natal.

I'ONS J H 1973. Effect of fertilizing and reinforcing tall grassveld on a duplex soil in Natal. Proceedings of the Grassland Society of Southern Africa 8, 61-63.

JANSEN VAN RENSBURG H 1939. A further contribution to the ecology of the Highveld grassland at Frankenwald, in relation to grazing. South African Journal of Science 36, 238-245.

JARMAN N G and BOSCH O J H 1973. The identification and mapping of extensive secondary invasive and degraded ecological types. In: Malan O G (ed) To assess the value of satellite imagery in resource evaluation on a national scale: 77-80. Pretoria. CSIR Special Report Fis 50, type 3 report for period July 1972 to November 1973.

JONES R I 1967a. Comparative effects of differential defoliation of grass plants in pure and mixed stands of two species. South African Journal of Agricultural Science 10, 429-444.

- JONES R I 1967b. Outline of a new approach to the study of competition. Proceedings of the Grassland Society of Southern Africa 2, 127-136.
- JONES R I 1971. Theoretical analysis of foraging efficiency of grazing animals. Proceedings of the Grassland Society of Southern Africa 6, 161-169.
- JONES R I 1978. Systems approach in Agriculture. Proceedings of the Grassland Society of Southern Africa 13, 21-25.
- JONES R I and BARTHOLOMEW P E 1971. A way to measure the spread of plants from a focus. Proceedings of the Grassland Society of Southern Africa 6, 170-175.
- JONES R I and CROSS G W 1971. Effect of selective defoliation on species in mixed swards. Proceedings of the Grassland Society of Southern Africa 6, 123-128.
- KILLICK D J B 1958. An account of the plant ecology of the Table Mountain area of Pietermaritzburg, Natal. Botanical Survey of South Africa Memoirs 32, 133 pp.
- KILLICK D J B 1963. An account of the plant ecology of the Cathedral Peak area of Natal Drakensberg. Botanical Survey of South Africa Memoirs 34, 178 pp.
- KILLICK D J B 1978. The Afro-alpine Region. In: Werger M J A (ed) Biogeography and Ecology in southern Africa. Junk, The Hague, pp 515-560.
- KING J 1916. Bird life in the Midlands of Natal. South African Journal of Science 13, 362-364.
- KING L 1978. The geomorphology of central and southern Africa. In: Werger M J A (ed) Biogeography and ecology in South Africa. Junk, The Hague, pp 3-18.
- KIRKBY D W 1971. Further investigation into the utilization of summer spared sourveld. Proceedings of the Grassland Society of Southern Africa 6, 63-68.
- KOMAREK E V 1971. Lightning and fire ecology in Africa. Proceedings of the Tall Timbers Fire Ecology Conference 11, 473-511.
- KRUGER J A and EDWARDS P J 1972. Benutting en relatiewe smaaklikheid van verskillende graspesies. Proceedings of the Grassland Society of Southern Africa 7, 146-155.
- KRUGER J A and SMIT I B J 1974. Die invloed van winterbrand en sny op die seisoenhooiproduksie van Eragrostis curvula (shrad) nees. Proceedings of the Grassland Society of Southern Africa 9, 117-122.
- KRUPKO I and DAVIDSON R L 1961. An experimental study of Stoebe vulgaris in relation to grazing and burning. Empire Journal of Experimental Agriculture 29, 176-180.

- LE ROUX C J G 1968. Veldbrand en maai sonder beweidings in die langrasveld van Natal. Unpublished Progress Report, South Africa. Department of Agriculture and Technical Services.
- LE ROUX C J G and HOWE L G 1983. Replacing Stipa trichotoma Nees (Nasella) in the eastern Cape. Proceedings of the Grassland Society of Southern Africa 18, 69-72.
- LEVEKIND L 1940. Gross evaporation from standard tanks in the Union of South Africa. South African Geographical Journal 22, 27-32.
- LIEBENBERG L C C 1934. Veld burning. How it affects the farmer as well as the country. Farming in South Africa 9, 213-215.
- LIVERSIDGE R 1962. Distribution of birds in relation to vegetation. Annals of the Cape Province Museum 2, 143-151.
- LIVERSIDGE R 1972. Grasses grazed by springbok and sheep. Proceedings of the Grassland Society of Southern Africa 7, 32-38.
- LOUW J G 1938. The influence of frequency of cutting on the yield, chemical composition, digestibility, and nutritive value of some grass species. Onderstepoort Journal of Veterinary Science and Animal Production 11, 163-243.
- LOUW W J 1951. An ecological account of the vegetation of the Pochefstroom area. Botanical Survey Memoirs 24, 105 pp.
- LOUW W J 1970. Klipveld studies. I. Checklist of the vegetation. Journal of South African Botany 36(3), 199-206.
- LOW J G 1969. Aspects of the morphological development of Themeda triandra (Forsk) and Eragrostis curvula-E. chloromelas complex. MSc Agric thesis, University of Pretoria.
- LOXTON R F 1966. A simplified soil-survey procedure for farm planning. Science Bulletin 383, 29 pp.
- LUDOLF R 1970. The land capability classification of the Natal region: agricultural land classification. Natal Town and Regional Planning Report.
- LUDOLF R and SCOTNEY D 1975. Soils of Lions River and Mooi River Valley soil conservation districts. Department of Agricultural and Technical Services, Technical Communication 94, 101 pp.
- MACVICAR C N, SCOTNEY D M, SKINNER T E, NIEHAUS H S and LOUBSER J H 1974. A classification of land (climate, terrain, form, soil) primarily for rain-fed agriculture. South African Journal of Agricultural Extension 3, 21-24.
- MACVICAR C N, DE VILLIERS J M, LOXTON R F, VERSTER E, LAMBRECHTS J J N, MERRYWEATHER F R, LE ROUX J and VON M HARMSE H J 1977. Soil classification, a binomial system for South Africa. 1st ed. Soils and Irrigation Research Institute. Department of Agricultural and Technical Services, Pretoria. 152 pp.

- MAKHANYA E M 1979. The use of land resources for agriculture in Lesotho. Dept of Geography, National University of Lesotho. Mazenod Institute.
- MALHERBE C E 1971. The results of certain sheep to cattle ratio experiments conducted on sourveld. Proceedings of the Grassland Society of Southern Africa 6, 69-77.
- MARKHAM R 1980. Prediction of annual rainfall in South Africa. Technical Report, CSIR, Pretoria, 21 pp.
- MARLOTH R 1905. On some aspects in the vegetation of South Africa which are due to the prevailing winds. South African Journal of Science 3, 215-218.
- MARLOTH R 1924. Notes on the question of veld burning. South African Journal of Science 21, 342-345.
- MATHEWS E D 1950. "Tukulu", the rebirth of a South African farm. Lovedale Press, Alice. 178 pp.
- MAUD R R 1978. Introduction and geomorphology of Natal and KwaZulu. In Agriculture and Environmental conservation in Natal and KwaZulu. Symp Wild Life soc. Sth Afr. and Royal Soc. of Sth Afr 9-14.
- MCGEE O S 1977. The Determination of Rainfall Seasons in South Africa using Markham's Technique. S.A. Geographer, April 1977. Vol. 5(5), 390-396.
- MCLACHLAN G R 1978. South African Red Data Book - reptiles and amphibians. South African National Scientific Programmes, CSIR, Report No 23, 53 pp.
- MCLACHLAN G R and LIVERSIDGE R 1970. Robert's birds of South Africa. 3rd ed. Trustees of South Africa Bird Book Fund, Cape Town, 504 pp.
- MEESTER J A J 1976. South African Red Data Book - small mammals. S A National Scientific Programmes, CSIR, Report No 11, 59 pp.
- MENTIS M T 1972. A review of some life history features of the large herbivores in Africa. The Lammergeyer 16, 1-89.
- MENTIS M T 1976a. Stocking rates for game. Proceedings of the Veld and Game Symposium. Hlabisa Soil Conservation Committee, 22-27.
- MENTIS M T 1976b. Veld/animal relationships. Proceedings of the Veld and Game Symposium. Hlabisa Soil Conservation Committee, 5-10.
- MENTIS M T 1977a. Is bush encroachment good or bad for game production. Proceedings of the Symposium on Veld and Bush Management for Beef and Game Production. Hlabisa Soil Conservation Committee, 23-37.
- MENTIS M T 1977b. Stocking rates and carrying capacities for ungulates on African rangelands. South African Journal of Wildlife Reserves 7, 89-98.

- MENTIS M T 1979. Hoofed game: asset or liability. Proceedings of the Hlabisa Soil Conservation Committee symposium 3, 71-81.
- MENTIS M T 1980a. The effect of animal size and adaptation on defoliation, selective defoliation, animal production and veld condition. Proceedings of the Grassland Society of Southern Africa 15, 147-151.
- MENTIS M T 1980b. Towards a scientific management of terrestrial ecosystems. South African Journal of Science 76, 536-540.
- MENTIS M T 1983. Towards objective veld condition assessment. Proceedings of the Grassland Society of Southern Africa 18, 77-80.
- MENTIS M T and BIGALKE R C 1973. Management for greywing and redwing francolins in Natal. Journal of the South African Wildlife Management Association 3, 41-47.
- MENTIS M T and BIGALKE R C 1979. Some effects of fire on two grassland francolins in the Natal Drakensberg.
- MENTIS M T and BIGALKE R C 1981. The effect of scale of burn on the densities of grassland francolins in the Natal Drakensberg. Biological Conservation 21, 247-261.
- MENTIS M T and COLLINSON R F H 1979. Management goals for wildlife reserves in grassveld and bushveld. Proceedings of the Grassland Society of Southern Africa 14, 71-74.
- MENTIS M T, COLLINSON R F H and WRIGHT M G 1980. The precision of assessing components of the condition of moist tall grassveld. Proceedings of the Grassland Society of Southern Africa 15, 43-46.
- MENTIS M T and DUKE R R 1976. Carrying capacities of natural veld in Natal for large wild herbivores. South African Journal of Wildlife Reserves 6, 65-74.
- MENTIS M T, MEIKLEJOHN M J and SCOTCHER J S B 1974. Veld burning in Giant's Castle Game Reserve, Natal Drakensberg. Proceedings of the Grassland Society of Southern Africa 9, 26-31.
- MENTIS M T and ROWE-ROWE D T 1979. Fire and faunal abundance and diversity in the Natal Drakensberg. Proceedings of the Grassland Society of Southern Africa 14, 75-77.
- MENTIS M T and TAINTON N M 1981. Stability, resilience and animal production in continuously grazed sour grassveld. Proceedings of the Grassland Society of Southern Africa 16, 37-43.
- MES M G 1952. The influence of some climatic factors on the growth and seed production of grasses. In: Veld Gold. National Veld Trust, Johannesburg, pp 39-51.
- MES M G 1956. The effect of some climatic factors on the growth, flowering and seed production of three species of grasses. Annual Review of Plant Physiology, 10-11.

- MES M G 1958. The influence of veld burning or mowing on the water, nitrogen and ash content of grasses. South African Journal of Science 54, 83-86.
- MES M G and AYMER-AINSLIE K M 1935. Studies on the water relations of grasses. I. Themeda triandra Forsk. South African Journal of Science 32, 280-304.
- MES M G and BOT G M 1938. Studies of the water relations of grasses. II. South African Journal of Science 35, 305-316.
- MILLER P M and BOOYSEN P de V 1968. The delineation of plant communities in relatively homogeneous grassland. Proceedings of the Grassland Society of Southern Africa 3, 43-50.
- MOLL E J 1968a. A plant ecological reconnaissance of the upper Mgeni catchment. Journal of South African Botany 34, 401-420.
- MOLL E J 1968b. A note on the aquatic vegetation of Midmar Dam, Howick, Natal. The Lammergeyer 9, 37-41.
- MOLL E J 1968c. A quantitative ecological investigation of the Krantzkloof forest, Natal. Journal of South African Botany 34, 15-25.
- MOLL E J 1976. The vegetation of the Three Rivers Region, Natal. Town and Regional Planning Report 33, 134 pp.
- MOLL E J 1978. A quantitative floristic study of a forest in Krantzkloof Nature Reserve, Natal. The Lammergeyer 26, 29-37.
- MOLL E J and WHITE F 1978. The Indian Ocean coastal belt. In: Werger M J (ed) Biogeography and Ecology in Southern Africa. Junk, The Hague, pp 561-598.
- MORRIS J W 1973. Automatic classification and ecological profiles of south-western Transvaal Highveld grassland. Unpublished PhD thesis, University of Natal.
- MORRIS J W 1976.(?) Automatic classification of the highveld grassland of Lichtenburg, south-western Transvaal. Bothalia 12, 267-292.
- MORRIS J W and GUILLERM J L 1974. The ecological profiles technique as applied to data from Lichtenburg, South Africa. Bothalia 11, 355-364.
- MORRIS J W and MÜLLER P J 1970. Seasonal variation of grassland basal cover. Proceedings of the Grassland Society of Southern Africa 5, 145-152.
- MOSTERT J W C 1957. Studies of the vegetation of parts of the Bloemfontein and Brandford districts. Memoirs of the Botanical Survey of South Africa 31, 226 pp.
- MOSTERT J W C 1967. Veld types, problems and pasture research in the Orange Free State. Proceedings of the Grassland Society of Southern Africa 2, 31-37.

- MOSTERT J W C and DONALDSON C H 1956. Veld burning: observations in the central Orange Free State. *Farming in South Africa* 32(6), 34-39.
- MOSTERT J W C, ROBERTS B R, HESLINGA C F and COETZEE P G F 1971. Veldbestuur in die Oranje Vrystaat-streek. Department of Agriculture, Bloemfontein. Technical Services Pamphlet No 391, 98 pp.
- MOTTRAM R and MINNAAR S 1975. Practical irrigation scheduling. *Crop Production* 4, 135-136.
- MUTANDAEDZA O T 1976. Effects of frequency and height of cutting on some tropical grasses and legumes. *Rhodesian Journal of Agricultural Research* 14, 21-37.
- MURRAY S M and GLOVER P 1935. A preliminary study of the root development of certain South African highveld grasses. *Journal of South African Botany* 1, 65-70.
- MUZZELL P J and BOOYSEN P de V 1969. The use of light-proof boxes for the measurement of plant vigour in cocksfoot (*Dactylis glomerata* L) and lucerne (*Medicago sativa* L). *Proceedings of the Grassland Society of Southern Africa* 4, 44-48.
- NAIDOO A and STEINKE D 1979. Effect of varying carbohydrate level on the uptake and translocation of ^{32}P in *Eragrostis curvula* (shrad) Nees. *Journal of South African Botany* 45, 231-241.
- NÄNNI U W 1956. Hydrological research at the Cathedral Peak Research Station. *Journal of the South African Forestry Association* 27, 2-35.
- NÄNNI U W 1960. The immediate effects of veld burning on streamflow in Cathedral Peak catchments. *Journal of the South African Forestry Association* 34, 13-27 or 7-12.
- NÄNNI U W 1969. Veld management in the Natal Drakensberg. *South African Forestry Journal* 68, 5-15.
- NÄNNI U W 1970. Management of Natal mountain catchments. Umgeni Catchment Association.
- NÄNNI U W 1972. Water use by riparian vegetation at Cathedral Peak. *South African Forestry Journal* 80, 1-10.
- NASH R and TAINTON N M 1975. Seasonal response of *Eragrostis curvula* to nitrogen. *Proceedings of the Grassland Society of Southern Africa* 10, 91-94.
- NDAWULA - SENYIMBA M S 1972. Some aspects of the ecology of *Themeda triandra*. *East African Agricultural and Forestry Journal* 38, 83-93.
- NEL L O 1983. *Elionurus muticus* in the Dohne Sourveld. *Proceedings of the Grassland Society of Southern Africa* 18, 84-88.
- NURSEY W R E 1971. Starch deposits in *Themeda triandra* Forsk. *Proceedings of the Grassland Society of Southern Africa* 6, 157-160.

ONESTA, P A and VERHOEF P 1976. Annual rainfall frequency distribution for 80 rainfall districts in South Africa. South African Journal of Science 72, 120-122.

OPPERMAN D P J and HUMAN J J 1977. Die invloed van ontblaring en vogstremming op die groeikragtigheid van Themeda triandra Forsk. Onder gekontroleerde toestande. Proceedings of the Grassland Society of Southern Africa 12, 65-69.

OPPERMAN D P J, HUMAN J J and VILJOEN M F 1977. Evapotranspirasie - studies op Themeda triandra Forsk. onder veldtoestande. Proceedings of the Grassland Society of Southern Africa 12, 71-76.

OPPERMAN D P J and ROBERTS B R 1974. Elyonurus argenteus Nees - A review. Proceedings of the Grassland Society of Southern Africa 9, 123-131.

OPPERMAN D P J and ROBERTS B R 1975. Evapotranspiration studies on Themeda triandra under field conditions: A study in lysimeter methodology. Proceedings of the Grassland Society of Southern Africa 10, 103-109.

OPPERMAN D P J and ROBERTS B R 1978. Die fenologiese ontwikkeling van Themeda triandra, Elyonurus argenteus en Heteropogon contortus onder veldtoestande in die sentrale Oranje-Vrystaat. Proceedings of the Grassland Society of Southern Africa 13, 135-140.

OPPERMAN D P J, ROBERTS B R and NEL L O 1974. Elyonurus argenteus - a review. Proceedings of the Grassland Society of Southern Africa 9, 123-131.

ORCHARD E R 1954. Soil characteristics and soil problems of the Natal agricultural region. Natal Regional Conference 4-7 May. Department of Agriculture, Pietermaritzburg, pp 10-18.

PEALING H 1918. On the effect of vegetation on the rainfall of South Africa. South African Journal of Science 14, 142-145.

PENTZ J A 1938. The value of botanical survey and the mapping of vegetation as applied to farming systems in South Africa. Memoirs of the Botanical Survey of South Africa 19, 1-15.

PENTZ J A 1945. An agro-ecological survey of Natal. Bulletin 250. Department of Agriculture and Forestry. 10 pp.

PENTZ J A 1949. An agro-ecological map of Natal. Pamphlet 250. Soil conservation and extension 7. Government Printer, Pretoria. 11 pp.

PENTZ J A 1963. Reclamation work in the Drakensberg Conservation Area and in northern Natal. Unpublished report. Natal Region, Department of Agriculture, Pietermaritzburg.

PENTZ J A and SCOTT J D 1952. The restoration of permanent streamflow in a South African river by the revegetation of its upper catchment. Proceedings of the VI International Grassland Congress, 1051-1055.

PENTZHORN K E W 1942. Burning veld out of season. Farming in South Africa 17, 453-454.

- PHILLIPS E P 1929. A brief sketch of the flora of the environs of Pretoria. South African Journal of Science 26, 184-189.
- PHILLIPS J 1930. Fire: its influence on biotic communities and physical factors in South and East Africa. South African Journal of Science 27, 352-367.
- PHILLIPS J 1936. Fire in vegetation: a bad master, a good servant and a national problem. Journal of South African Botany 2, 35-45.
- PHILLIPS J 1959. Agriculture and ecology in Africa: a study of actual and potential development south of the Sahara. Praeger, New York. 423 pp.
- PHILLIPS J 1965. Trans-Saharan Africa forty years onward - some ecological and related changes. South African Journal of Science 61, 191-198.
- PHILLIPS J 1973. The agriculture and related development of the Tugela Basin and its influent surroundings. Natal Town and Regional Planning Report 19, 300 pp.
- PHILLIPS J F V 1971. Physionomic classification of the more common vegetation types in South Africa including Mocambique. Loxton R F, Hunting and Associates, Johannesburg, 52 pp.
- PHILLIPS J P 1965. Fire - as master and servant: its influence in the bioclimatic regions of Trans-Saharan Africa. Proceedings of the Fourth Annual Tall Timbers Fire Ecology Conference 4, 7-110.
- PIENAAR A J 1966. Die groeivermoë en anorganisasie samestelling van vier grassoorte onder differensiële voeding en vogvoorsiening. DSc agric thesis, University of Pretoria.
- PIENAAR A J 1968. Beheerde selektiewe bewelding. Landbouweekblad June 11, 40-41.
- PIENAAR A J 1968. Veld control in the mixed sourveld regions of South Africa. In: Hugo W J (ed) The small stock industry in South Africa. Department of Agricultural Technical Services, Pretoria, 34 pp.
- PIENAAR U de V 1974. Habitat-preference in South African antelope species and its significance in natural and artificial distribution patterns. Koedoe 17, 185-195.
- PITMAN W V, MIDDLETON B J and MIDGLEY D C 1981. Surface water resources of South Africa. Vol VI, Part 1, Hydrological Research Unit Report No 9/81.
- POLE-EVANS I B 1920. The veld: its resources and dangers. South African Journal of Science 17, 1-34.
- POLE-EVANS I B 1936. A vegetation map of South Africa. Memoirs of the Botanical Survey of South Africa 15, 1-23.
- POTTS G 1923. The plant succession in the Orange Free State, and the need for maintaining a covering of vegetation. South African Journal of Science 20, 196-201.

POTTS G and TIDMARSH C E 1937. An ecological study of a piece of karoo-like vegetation near Bloemfontein. *Journal of South African Botany* 3, 51-93.

PRELLER J H 1948. Grazing management. *Farming in South Africa* 23, 191-199.

PRETORIUS M W, GRUNOW J O and RABIE J W 1974. Invloed van frekwensie en intensiteit van ontblaring op produksie en morfologiese ontwikkeling van Panicum maximum. *Proceedings of the Grassland Society of Southern Africa* 9, 111-115.

RABIE J W 1954. Studies on the growth and development of veld grasses with special reference to Eragrostis curvula and Themeda triandra. MSc thesis, University of Natal.

RETHMAN N F G 1965. Studies on grass growth in a tall grassveld sward. MSc thesis, University of Natal.

RETHMAN N F G 1971. Elevation of shoot apices of two ecotypes of Themeda triandra on the Transvaal Highveld. *Proceedings of the Grassland Society of Southern Africa* 6, 86-92.

RETHMAN N F G 1973. Eragrostis curvula (weeping lovegrass): a review with special reference to southern Africa. Technical Communication 116. Department of Agricultural Technical Services, 12 pp.

RETHMAN N F G and BOOYSEN P de V 1966. Rooigrasveld management for seeding. *Farming in South Africa* 42(1), 9 and 20.

RETHMAN N F G and BOOYSEN P de V 1967. Growth and development of Cymbopogon excavatus tillers. *South African Journal of Agricultural Science* 10, 811-822.

RETHMAN N F G and BOOYSEN P de V 1968a. Growth and development in Heteropogon contortus tillers. *South African Journal of Agricultural Science* 11, 259-272.

RETHMAN N F G and BOOYSEN P de V 1968b. The influence of time of defoliation on the vigour of a tall grassveld sward in the next season. *Proceedings of the Grassland Society of Southern Africa* 3, 91-94.

RETHMAN N F G and BOOYSEN P de V 1969. The seasonal growth patterns of a Tall Grassveld Sward. *Proceedings of the Grassland Society of Southern Africa* 4, 56-60.

RETHMAN N F G and MALHERBE C E 1970. The influence of fertilization on the production and digestibility of natural veld. *Agroplantae* 2, 43-44.

RETHMAN N F G, BEUKES B H and MALHERBE C E 1971. Influence on a north-eastern sandy highveld sward of winter utilization by sheep. *Proceedings of the Grassland Society of Southern Africa* 6, 55-62.

RETHMAN N F G and MALHERBE C E 1972. Plant pastures or fertilized veld? *Farming in South Africa* 48(8), 82-83.

- RETHMAN N F G and BEUKES B H 1973. Overseeding of Eragrostis curvula on north eastern sandy highveld. Proceedings of the Grassland Society of Southern Africa 8, 57-59.
- RINEY T and KETTLITZ W L 1964. Management of large animals in the Transvaal. Mammalia 28, 189-248.
- ROBERTS B R 1963. Ondersoek in die plantegroei van die Willem Pretorium Wildtuin met spesiale verwysing na veldbenutting. Koedoe 6, 137-164.
- ROBERTS B R 1965. Veld management - the cornerstone of conservation. Leaflet 19. Department of Agricultural Technical Services, 22 pp.
- ROBERTS B R 1966. The ecology of Thaba'Nchu - a study of vegetation/habitat relationships. PhD thesis, University of Natal.
- ROBERTS B R 1969a. Application of veld management in South Africa - an analysis of progress. Proceedings of the Grassland Society of Southern Africa 4, 92-98.
- ROBERTS B R 1969b. The vegetation of the Golden Gate Highlands National Park. Koedoe 12, 15-28.
- ROBERTS B R 1969c. The multi-camp controversy - a search for evidence. Proceedings of the Veld Management Conference May 1969, 41-57 pp.
- ROBERTS B R 1970. Assessment of veld condition and trend. Proceedings of the Grassland Society of Southern Africa 5, 137-139.
- ROBERTS B R 1970. Why multi-camp layouts? Proceedings of the Grassland Society of Southern Africa 5, 17-22.
- ROBERTS B R 1971. Habitat references of twenty-seven grasses. Proceedings of the Grassland Society of Southern Africa 6, 44-49.
- ROBERTS B R 1973. Common grasses of the Orange Free State. Miscellaneous Publication 3. Provincial Administration, Bloemfontein.
- ROBERTS B R 1975. Microclimatic differences in habitat on a high mountain in the Orange Free State. Proceedings of the Grassland Society of Southern Africa 10, 49-55.
- ROBERTS B R, ANDERSON E R and FOURIE J H 1975. Evaluation of natural pastures: quantitative criteria for assessing condition in the Themeda veld of the Orange Free State. Proceedings of Grassland Society of Southern Africa 10, 133-140.
- ROBERTS B R and FOURIE J H 1975. Common grasses of the northern Cape. Sendingysers, Bloemfontein, 131 pp.
- ROBERTS B R and OPPERMAN D P J 1966. The influence of defoliation on carbohydrate status and nutritive value of perennial veld grasses. Proceedings of the Tenth International Grassland Congress, 940-944.

ROBERTS B R and OPPERMAN D P J 1974. Veld management recommendations - a reassessment of key species and proper use factors. Proceedings of Grassland Society of Southern Africa 9, 149-155.

ROBINSON E R, ELIZABETH GIBBS RUSSEL G, TROLLOPE W S W and DOWNING B H 1979. Short term burning treatments and ecological interactions in the herb layer of false thornveld of the eastern Province. Proceedings of the Grassland Society of Southern Africa 14, 79-83.

RODEL M G 1952. The effects of different intensities of defoliation on veld and yields and root development of certain grass species. MSc thesis, University of Natal.

ROOS J H, RETHMAN N F G and KOTZE G D 1973. Preliminary results on species selection by animals on sour grassveld. Proceedings of Grassland Society of Southern Africa 8, 77-81.

ROSS J C 1963. Soil conservation in South Africa, a review of the problems and developments to date. Department of Agriculture Technical Services, Pretoria, 84 pp.

ROSS J H 1972. The flora of Natal. Botanical Survey of South Africa Memoirs 39, 418 pp.

ROSS J H 1973. An analysis of the flora of Natal. Bothalia 11, 103-106.

ROUX E 1954. The nitrogen sensitivity of Eragrostis curvula and Trachypogon plumosus in relation to grassland succession. South African Journal of Science 50, 173-176.

ROUX E 1969. Grass - a story of Frankenwald. Oxford University Press, Cape Town, 212 pp.

ROUX P W 1963. The descending-point method of vegetation survey. South African Journal of Agricultural Science 6, 273-288.

ROUX P W 1967. The immediate effects of intensive grazing of mixed karoo veld. Proceedings of the Grassland Society of Southern Africa 2, 93-90.

ROUX P W 1968. Principles of veld management in the karoo and the adjacent dry sweet grass veld. In: Hugo W J (ed) The small stock industry in South Africa. Government Printer, Pretoria, 318 pp.

ROWE-ROWE D T 1972. Some aspects of antelope ecology in Giant's Castle Game Reserve. Typescript. Natal Parks Board, Pietermaritzburg.

ROWE-ROWE D T 1978. The small carnivores of Natal. The Lammergeyer 25, 1-48.

RUTHERFORD M C 1976. Change of biomass in some perennial grass species. Proceedings of the Grassland Society of Southern Africa 11, 43-46.

RUTHERFORD M C 1978. Primary production ecology in southern Africa. In: Biogeography and ecology in southern Africa. Werger M J A (ed). Junk, The Hague, pp 621-659.

- RUTHERFORD M C 1980. Annual plant production - precipitation relations in arid and semi-arid regions. South African Journal of Science 76, 53-56.
- SANDER C J 1970. Estimation of yield of veld with an electronic capacitance instrument. Proceedings of the Grassland Society of Southern Africa 5, 132-136.
- SAVAGE M J 1980. The effects of fire on the grassland microclimate. Herbage Abstracts 50, 589-603.
- SAVAGE M J and VERMEULEN K 1983. Microclimate modification of Tall Moist Grasslands of Natal by spring burning. Journal of Range Management 36(2), 172-174.
- SAVORY A 1978. A holistic approach to range management using short duration grazing. 1st International Rangeland Congress, Denver, 555-557.
- SCHEEPERS J C 1969. A preliminary assessment of association - analysis in the Kroonstad area. Proceedings of the Grassland Society of Southern Africa 4, 78-83.
- SCHEEPERS J C 1975. The plant ecology of the Kroonstad and Bethlehem areas of the Highveld Agricultural Region. DSc thesis, University of Pretoria.
- SCHOEMAN S L 1939. Investigations on 1. The viable seed content of veld and 2. The effect of seasonal grazing and cutting on the top growth and the root systems of natural veld and certain indigenous species. MSc thesis, University of Pretoria.
- SCHULZE B R 1965. Climate of South Africa Part 8: General survey. Weather Bureau 28. Government Printer, Pretoria, 330 pp.
- SCHULZE R E 1974. Catchment evapotranspiration in the Natal Drakensberg. PhD thesis, University of Natal, Pietermaritzburg.
- SCHULZE R E 1979a. Soil loss in the key area of the Drakensberg: a regional model for southern Africa (SLEMSA). Paper read at the one day symposium of SAIAE, 30 March 1979, Pietermaritzburg, 11 pp.
- SCHULZE R E 1979b. Hydrology and water resources of the Drakensberg. Natal Town and Regional Planning Commission, Pietermaritzburg, 179 pp.
- SCHULZE R E 1980a. The distribution of kinetic energy of rainfall in South Africa - a first assessment. Water in South Africa 6, 49-58.
- SCHULZE R E 1980b. The land use component in hydrological modelling: an evaluation. University of Natal, Pietermaritzburg, Department of Agricultural Engineering, ACRU Report, 9.
- SCHULZE R E 1981b. Estimates of storm runoff and sediment yield for selected dam sites in KwaZulu. University of Natal Pietermaritzburg, Department of Agricultural Engineering ACRU Report No 12, 75 pp.

- SCHULZE R E 1982. Agrohydrology and climatology of Natal. Agricultural catchments Unit Report No 1. Water Research Commission, 136.
- SCHULZE R E and EASTER M L 1980. The distribution of kinetic energy of rainfall in the sugar belt of Natal. Proceedings of the South African Sugar Technologists' Association 6, 181-183.
- SCHULZE R E and MCGEE O S 1980. Climate indices and classifications in relation to the biogeography of southern Africa. In: Werger M J A (ed) Biogeography and Ecology in South Africa. Junk, The Hague, pp 21-52.
- SCOTCHER J S B and CLARKE J C 1981. Effects of certain burning treatments on veld condition in Giants Castle Game Reserve. Proceedings of the Grassland Society of Southern Africa 16, 121-127.
- SCOTCHER J S B, WRIGHT M G, WRIGHT C W and COLLINSON R F H 1978. An evaluation of veld condition in Moor Park Nature Reserve. Lammergeyer 26, 7-18.
- SCOTCHER J S B, ROWE-ROWE D T, CLARKE J and LOWRY P B 1979. Fire ecology of the Natal Drakensberg. Unpublished report.
- SCOTNEY D M 1970. Vleis of Natal - definition and distribution. In: Shone F K (ed) Vleis of Natal Symposium. South African Institute of Agricultural Extension.
- SCOTNEY D M 1971. Land capability classification - a basis for farm conservation planning. Proceedings of the Grassland Society of Southern Africa 6, 101-107.
- SCOTNEY D M 1978. The present situation in Natal. In: Agriculture and environmental conservation in Natal and KwaZulu.
- SCOTT J D 1937. The possibilities of reseeding damaged veld and old lands. South African Journal of Science 33, 617-624.
- SCOTT J D 1947. Veld management in South Africa. Science Bulletin 278. Department of Agriculture, Union of South Africa, 40 pp.
- SCOTT J D 1951. A contribution to the study of the problems of the Drakensburg area. Bulletin 324. Department of Agriculture, Union of South Africa, 164 pp.
- SCOTT J D 1955. Principles of veld management. In: Meredith D (ed) The grasses and pastures of South Africa. Central News Agency, Johannesburg, pp 601-623.
- SCOTT J D 1956. The study of primordial buds and the reaction of roots to defoliation as the basis of grassland management. Proceedings of the 7th International Grassland Congress, 479-487.
- SCOTT J D 1966. Veld burning in South Africa. African Wildlife 20, 93-102.
- SCOTT J D 1967. Bush encroachment in South Africa. South African Journal of Science 63, 311-314.

SCOTT J D 1970. Pros and cons of eliminating veld burning. Proceedings of the Grassland Society of Southern Africa 5, 23-26.

SCOTT J D 1971. Veld burning in Natal. Proceedings of the Annual Tall Timbers Fire Ecology Conference 11, 33-51.

SCOTT J D, PENTZ J A and FISHER A 1955. Soil-moisture and soil erosion. Proc. Hydrol Conference, Pretoria.

SCOTT J D and RABIE J W 1956. Preliminary studies on growth and development of Eragrostis curvula and Themeda triandra. South African Journal of Science 52, 207-210.

SHANTZ H L and TURNER B L 1958. Photographic documentation of vegetation changes in Africa over a third of a century. University of Arizona College of Agriculture. Report 169, 158 pp.

SIEGFRIED W R, FROST P G H, COOPER J and KEMP A C 1976. South African Red Data Book - Aves. South African National Scientific Programmes, CSIR Report No 7, 108 pp.

SKINNER J D 1970. The significance of the breeding season in some ungulates in southern Africa. Journal of South African Biological Society 11, 25-28.

SKINNER J D, FAIRALL N and BOTHMA J du P 1977. South African Red Data Book - large mammals. South African National Scientific Programmes, CSIR, Report No 18, 29 pp.

SKINNER T E 1976. A comparison between the effects of continuous grazing by Angora goats and Merino sheep on veld in the central lower Karoo. Proceedings of the Grassland Society of Southern Africa 11, 131-134.

SMIT I B J 1955. The slangbos problem. Farming in South Africa 30, 479-481.

SMUTS J C 1926. Holism and evolution. MacMillan, London.

SNYMAN H A and OPPERMAN D P J 1983. The effects of moisture and defoliation treatments in hydrological units on natural velds of the central Orange Free State. Proceedings of the Grassland Society of Southern Africa 18, 124-130.

SNYMAN H A, OPPERMAN D P J and VAN DEN BERG J A 1980. Hidrologiese siklus en waterverbruiksdoeltreffendheid van veld in verskillende suksessiestadia. Proceedings of the Grassland Society of Southern Africa 15, 69-72.

SOUSA DE ALMEIDA F 1974. Bush control in grassland by aerial spraying. Proceedings of the Grassland Society of Southern Africa 9, 73-76.

STAPLES R R 1930. Studies in veld management. Science Bulletin 91. Department of Agriculture, Union of South Africa, 31 pp.

STEAD A 1921. The value of the paddock system. Union of South Africa, Agricultural Journal 8, 6 pp.

- STEINKE T D 1968. A preliminary study of tillering in veld grasses. South African Journal of Agricultural Science 11, 435-441.
- STEINKE T D 1969. The translocation of C^{14} assimilates in Eragrostis curvula: an autoradiographic survey. Proceedings of the Grassland Society of Southern Africa 4, 19-34.
- STEINKE T D 1975. Effect of height of cut on translocation of ^{14}C - labelled assimilates in Eragrostis curvula (shrad.) nees. Proceedings of the Grassland Society of Southern Africa 10, 41-47.
- STEINKE T D and BOOYSEN P de V 1968. The regrowth and utilization of carbohydrate reserves of Eragrostis curvula after different frequencies of defoliation. Proceedings of the Grassland Society of Southern Africa 3, 105-110.
- STEINKE T D, CARSER A J and THERON E P 1970. Translocation of paraquat in some veld grasses. Proceedings of the Grassland Society of Southern Africa 5, 94-100.
- STEINKE T D and NEL L O 1967. The growth of veld in response to defoliation by various means in the late winter and spring. Proceedings of the Grassland Society of Southern Africa 2, 113-117.
- STEYN T J 1961. Farm planning and nature conservation. Fauna and Flora 12, 5-7.
- STORY R 1952. A botanical study of the Keiskammahoek district. Botanical Survey of South Africa Memoirs 27, 1-184.
- STUART-HILL G C and MENTIS M T 1982. Coevolution of African grasses and large herbivores. Proceedings of the Grassland Society of Southern Africa 17, 122-128.
- STUCKENBERG B R 1969. Effective temperature as an ecological factor in southern Africa. Zoologica Africana 4(2), 145-197.
- SUMNER M E 1957. The physical and chemical properties of tall grassveld soils of Natal in relation to their erodibility. MSc thesis, University of Natal.
- SYMONS L B and JONES R I 1971. An analysis of available techniques for estimating production of pastures without clipping. Proceedings of the Grassland Society of Southern Africa 6, 185-190.
- TAINTON N M ed 1981. Veld and pasture management in South Africa. Shuter & Shooter in association with Natal University Press, Pietermaritzburg.
- TAINTON N M 1958. Studies on the growth and development of certain veld grasses with special reference to defoliation. MSc thesis, University of Natal.
- TAINTON N M 1963. Burning or mowing - which is more profitable? Farming in South Africa 39(8), 24-25.

TAINTON N M 1964. Developmental morphology of the apical meristem of Themeda triandra (Forsk). South African Journal of Agricultural Science 7, 93-100.

TAINTON N M 1969. Environmental control of flowering in tropical-subtropical grasses. Proceedings of the Grassland Society of Southern Africa 4, 49-55.

TAINTON N M 1971. An analysis of the objectives of resting grassveld. Proceedings of the Grassland Society of Southern Africa 6, 50-54.

TAINTON N M 1972. The relative contribution of overstocking and selective grazing to the degeneration of tall grassveld in Natal. Proceedings of the Grassland Society of Southern Africa 7, 39-43.

TAINTON N M 1977. Grazing management and the bush/grass balance. Proceedings of the symposium on Veld and Bush Management for Beef and Game Production. Hlabisa Soil Conservation Committee, 8-22.

TAINTON N M 1978. Fire in the management of humid grasslands in South Africa. Proceedings of the International Range Congress 1, 684-686.

TAINTON N M 1981. The ecology of the main grazing lands of South Africa. In: Veld and pasture management in South Africa. N M Tainton ed. Shuter & Shooter in association with Natal University Press, Pietermaritzburg.

TAINTON N M 1981a. The ecology of the main grazing lands of South Africa. In: Veld and Pasture Management in South Africa. N M Tainton ed. Shuter & Shooter in association with Natal University press, 27-41.

TAINTON N M 1981b. Veld burning. In: Veld and Pasture Management in South Africa. M N Tainton ed. Shuter & Shooter in association with Natal University Press, 363-381.

TAINTON N M and BOOYSEN P de V 1963. The effects of management on apical bud development and seeding in Themeda triandra and Tristachya hispida. South African Journal of Agricultural Science 6, 21-30.

TAINTON N M and BOOYSEN P de V 1964a. Growth and development in perennial veld grasses. I. Themeda triandra tillers under various systems of defoliation. South African Journal of Agricultural Science 8, 93-110.

TAINTON N M and BOOYSEN P de V 1964b. Growth and development in perennial veld grasses. II. Hyparrhenia hirta tillers under various systems of defoliation. South African Journal of Agricultural Science 8, 745-760.

TAINTON N M, BOOYSEN P de V, BRANSBY DI and NASH R C 1978. Long term effects of burning and mowing on tall grassveld in Natal: dry matter production. Proceedings of the Grassland Society of Southern Africa 13, 41-44.

TAINTON N M, BOOYSEN P de V, and NASH R C 1977. The grazing rotation: effects of different combinations of presence and absence. Proceedings of the Grassland Society of Southern Africa 12, 103-104.

- TAINTON N M, BOOYSEN P de V, and SCOTT J D 1970. Response of tall grassveld to different intensities, seasons and frequencies of clipping. Proceedings of the Grassland Society of Southern Africa 5, 32-41.
- TAINTON N M, BRANSBY D I and BOOYSEN P de V 1976. Common veld and pasture grasses of Natal. Shuter and Shooter, Pietermaritzburg.
- TAINTON N M, and EDWARDS P J 1979. Veld condition assessment. Proceedings of the Symposium on Beef and Game Management. Hlabisa Soil Conservation Committee, 32-40.
- TAINTON N M, EDWARDS P J and MENTIS M T 1980. A revised method for assessing veld condition. Proceedings of the Grassland Society of Southern Africa 15, 37-42.
- TAINTON N M, FORAN B D and BOOYSEN P de V 1978. The veld condition score: an evaluation in situations of known past management. Proceedings of the Grassland Society of Southern Africa 13, 35-40.
- TAINTON N M, GROVES R H, and NASH R C 1977. Time of mowing and burning veld: short term effects on production and tiller development. Proceedings of the Grassland Society of Southern Africa 12, 59-64.
- TAINTON N M and MENTIS M T 1984. Fire in grassland. In: Ecological effects of fire in South Africa. P de V Booysen and N M Tainton eds. Ecological Studies 48. Springer-Verlag.
- TEW J, ELLY S, GROSSMAN P and CRESWELL C F 1974. A study of the fine structure, enzyme activities and pattern of ^{14}C incorporation of highveld grasses from different successional stages. Proceedings of the Grassland Society of Southern Africa 9, 95-104.
- THERON E P 1966. A study of certain chemical and physical properties of ten indigenous grasses and their relationship to animal p-reference. PhD thesis, University of Natal.
- THERON E P 1970. The potential of vleis pastures in Natal. In: Stone F K (ed) Vleis of Natal Symposium. South African Institute of Agricultural Extension.
- THERON E P 1975. Potential for the radical improvement of the Highland Sourveld. The Fertilizer Society of South Africa Journal 1, 73-79.
- THERON E P and BOOYSEN P de V 1966. Palatability in grasses. Proceedings of the Grassland Society of Southern Africa 1, 11-120.
- THERON E P, LESCH S F and MAPPLEDORAM B D 1974. The potential in Natal for the radical improvement of the veld and the fortification of established pastures. Proceedings of the Grassland Society of Southern Africa 9, 175-178.
- THERON E P, GROVÉ J S, ARNOTT K K AND CHUTTER D J 1975. The Cedara pasture seeder. Proceedings of the Grassland Society of Southern Africa 10, 73-76.

THERON G C 1937. Veld management investigations at the School of Agriculture, Potchefstroom. Preliminary report. Bull. Dept. Agric. S. Afr. No. 166.

THOMPSON W R 1936. Veld burning: its history and importance in South Africa. In: Thompson W R (ed) Moisture and farming in South Africa. Central News Agency, Johannesburg, pp 206-226.

THOMPSON W R 1975. A photographic technique to quantify lateral cover density. Journal of the South African Wildlife Management Association 5, 75-79.

THORRINGTON-SMITH, ROSENBERG and MCCRYSTAL 1978. Towards a plan for KwaZulu Ulundi, KwaZulu Government.

TIDMARSH C E 1948. Conservation problems of the Karoo. Farming in South Africa 23, 519-530.

TIDMARSH C E M 1952. Climate and grass. In Veld Gold. National Veld Trust, Johannesburg.

TIDMARSH C E M 1957. Weiveldbeheer in die Karoo en aangrensende soetveldstreke. Jaarboek vir Boere in Suid-Afrika. Staatsdrukker, Pretoria, 663-644.

TIDMARSH C E M and HAVENGA C M 1955. The wheel point method of survey and measurement of semi-open grasslands and Karoo vegetation in South Africa. Botanical Survey of South Africa Memoirs 29, 49 pp.

TIEDMAN J A and WIELAND R G 1983. The use of microplots to sample grassveld in Lesotho. Proceedings of the Grassland Society of Southern Africa 18, 143-146.

TROLLOPE W S W 1974. Role of fire in preventing bush encroachment in the eastern Cape. Proceedings of the Grassland Society of Southern Africa 9, 67-72.

TROLLOPE W S W 1973. Fire as a method of controlling Macchia (Fynbos) vegetation on the Amatole mountains of the eastern Cape. Proceedings of the Grassland Society of Southern Africa 8, 35-41.

TROLLOPE W S W 1977. Overview of bush control. Proceedings of the Symposium on Veld and Bush Management for Beef and Game Production. Hlabisa Soil Conservation Committee, 38-53.

TROLLOPE W S W 1978a. Fire behaviour - a preliminary study. Proceedings of the Grassland Society of Southern Africa 13, 123-128.

TROLLOPE W S W 1978b. Fire - a rangeland tool in South Africa. Proceedings of the International Rangeland Congress 1, 235-247.

TROLLOPE W S W 1980. Controlling bush encroachment with fire in the savanna area of South Africa. Proceedings of the Grassland Society of Southern Africa 15, 173-177.

TROLLOPE W S W 1982. Veld rehabilitation and management studies in the Ciskei. Control of bush encroachment with fire and goats. Final report. University of Fort Hare.

TROLLOPE W S W 1983. Fire in the savanna. In: Ecological effects of fire in South Africa. P de V Booysen and N M Tainton eds. Ecological Studies 48, Springer-Verlag.

TROLLOPE W S W and BOOYSEN P de V 1971. The eradication of Macchia (Fynbos) vegetation on the Amatole mountains of the eastern Cape. Proceedings of the Grassland Society of Southern Africa 6, 28-38.

TURNER J L 1970. Some notes on the occurrence of vleis in Natal and adjacent areas. In: Skone F K (ed) Vleis of Natal Symposium. South African Institute of Agricultural Extension.

TYSON P D 1978. Rainfall changes over South Africa during the period of meteorological record. In: Werger M J A (ed) Biogeography and Ecology of southern Africa. Junk, The Hague, pp 55-69.

TYSON P D and DYER T G T 1978. The predicted above-normal rainfall of the seventies and the likelihood of droughts in the eighties in South Africa. South African Journal of Science 74, 372-377.

VAN BRUGGEN A C 1970. The terrestrial Mollusca of the Mkusi and Ndumu Game Reserves in Zululand. The Lammergeyer 11, 58-59.

VAN DEN BERG J A 1972. Invloed van seisoensbeweiding op Cymbopogon-Themeda veld. MSc (Agric) thesis, University of the Orange Free State.

VAN DEN BERG J A, ROBERTS B R and VORSTER L F 1975. Die uitwerking van seisoenbeweiding op die bedekking en samestelling van Cymbopogon - Themeda veld. Proceedings of the Grassland Society of Southern Africa 10, 111-117.

VAN DEN BERG J A, ROBERTS B R and VORSTER L F 1976. Die uitwerking van seisoenbeweiding op die infiltrasievermoë van gronde in 'n Cymbopogon - Themeda veld. Proceedings of the Grassland Society of Southern Africa 11, 91-95.

VAN DER EYK J J, MACVICAR C N and DE VILLIERS J M 1969. Soils of the Tugela Basin. Natal Town and Regional Planning Report 15, 50 pp.

VAN DER MERWE C R 1962. Soil groups and sub groups of South Africa. Science Bulletin 356, Department of Agricultural and Technical Services, South Africa, 355 pp.

VAN DER RIET P 1980. Cooperative water resources development in southern Africa. Report No 5/80. Hydrological Research Unit, University of Witwatersrand, Johannesburg.

VAN DER SCHIJFF H P 1964. 'n Hervaluasie van die probleem van bosindringing in Suid Afrika. Tydskrif Natuurwetenskappe 4, 67-80.

VAN DER WALT J L 1962. Onderzoek na 'n objektiewe metode van plantopname in die Sneeubergreeks. MSc thesis, University of Pretoria.

VAN DER WESTHUIZEN F G J, VAN DEN BERG J A and OPPERMAN D P J 1978. Die benutting van grasveld in die sentrale Oranje-Vrystaat met skape. Proceedings of the Grassland Society of Southern Africa 13, 83-89.

VAN RENSBURG H J 1941. A comparison of quadratic results and phenological data in a series of Highveld grassland grazing experiments subjected to different treatments over a period of six years. South African Journal of Science 38, 186-197.

VAN RENSBURG H J 1972. Fire: it's effect on grasslands, including swamps - southern, central and eastern Africa. Proceedings of the Tall Timbers Fire Ecology Conference 11, 175-199.

VAN RENSBURG P H J J 1971. Soil cultivation and the sowing of Eragrostis curvula on severely damaged Themeda-Cymbopogon veld. Proceedings of the Grassland Society of Southern Africa 6, 93-100.

VAN TONDER G 1969. The planning and execution of a multicamp system. Farmers Weekly 30, 36-40.

VAN VUREN J P J 1961. Nature conservation on farms. African Wildlife 15, 231-239.

VAN ZINDEREN BAKKER E M 1978. Quaternary vegetation changes in southern Africa. In: Werger M J A (ed) Biogeography and ecology in southern Africa. Junk, The Hague, pp 133-142.

VAN ZYL J H M 1965. The vegetation of the South African Lombard Nature Reserve and its utilization by certain antelope. Zoologica Africana 1, 55-72.

VENTER A D 1962. Studies on the Ngongoni veld of the Natal mistbelt. MSc thesis, University of Natal.

VENTER A D 1968. The problems of Aristida junciformis encroachment into the veld of Natal. Proceedings of the Grassland Society of Southern Africa 3, 163-165.

VENTER A D and DREWES R H 1968. Veld utilization during winter. Farming in South Africa 44(4), 41.

VENTER A D and DREWES R H 1969. A flexible system of management. Proceedings of the Grassland Society of Southern Africa 4, 104-107.

VINES R G 1980. Analyses of South African rainfall. South African Journal of Science 76, 404-409.

VISSER J H 1959. Fertilizing veld: not economically justified. Farming in South Africa 35(6), 26-27.

VISSER J H 1966. Bemesting van die veld. Proceedings of the Grassland Society of Southern Africa 1, 41-48.

- VOGEL J C, FULS A and ELLIS R P 1978. The geographical distribution of kranz grasses in South Africa. South African Journal of Science 74, 204-215.
- VON BROEMSEN H H 1965. A wheel point apparatus for the survey and measurement of open and semi-open savanna vegetation. Proceedings of the Ninth International Grassland Congress 2, 1345-1348.
- VON GINKEL B 1969. Bemesting van 'n Cymbopogon - Themeda - veldtipe. Tegniese mededeling 98. Department of Agricultural and Technical Services, Pretoria, 11 pp.
- VON LA CHEVALLERIE M 1970. Meat production from wild ungulates. Proceedings of the South African Society of Animal Production 9, 73-87.
- VON RICHTER W 1974. Survey of the adequacy of existing conserved areas in relation to wild animal species. Koedoe 17, 39-69.
- VORSTER L F 1975. The influence of prolonged seasonal defoliation on veld yields. Proceedings of the Grassland Society of Southern Africa 10, 119-122.
- VORSTER L F and MOSTERT J W C 1968. Veld fertilization trends over a decade in the central Orange Free State. Proceedings of the Grassland Society of Southern Africa 3, 111-119.
- VORSTER L F and VISAGIE A F J 1980. Die invloed van aantal kampe en veegetalle op diereproduksie en veld toestand. Proceedings of the Grassland Society of Southern Africa 15, 131-135.
- VORSTER M 1982. The development of the ecological index method for assessing veld condition in the karoo. Proceedings of the Grassland Society of southern Africa 19, 84-89.
- WALKER B H 1970. An evaluation of eight methods of botanical analysis of grasslands in Rhodesia. Journal of Applied Ecology 7, 403-411.
- WALKER B H 1974. An appraisal of the systems approach to research on and management of African wildlife ecosystems. Journal of the South African Wildlife Management Association 4, 129-135.
- WALKER B H 1976. An assessment of the ecological basis of game ranching in South African savannas. Proceedings of the Grassland Society of Southern Africa 11, 125-130.
- WALKER B H 1978. The systems approach to ecological research. Proceedings of the Grassland Society of Southern Africa 13, 17-20.
- WALKER B H 1980. Stable production versus resilience: a grazing management conflict? Proceedings of the Grassland Society of Southern Africa 15, 79-83.
- WALKER B H, LUDWIG D, HOLLING C S and PETERMAN R M 1981. Stability of semi-arid savanna grazing systems. Journal of Ecology 69, 473-478.

- WEINBRENN C 1938. A comparative study of the osmotic values of the leaf saps of certain highveld grasses. South African Journal of Science 35, 317-318.
- WEINBRENN C 1939. Further investigation on the osmotic values of the leaf saps of certain highveld grasses. South African Journal of Science 36, 265-269.
- WEINMANN H 1940a. Seasonal chemical changes in the roots of some South African Highveld grasses. Journal of South African Botany 6, 131-145.
- WEINMANN H 1940b. Storage of root reserves in Rhodes grass. Plant Physiology 15, 467-484.
- WEINMANN H 1942. On the autumnal remigration of nitrogen and phosphorus in Trachypogon plumosus. Journal of South African Botany 7, 179-196.
- WEINMANN H 1943. Effects of defoliation intensity and fertilizer treatment on Transvaal Highveld. Empire Journal of Experimental Agriculture II, 113-124.
- WEINMANN H 1944. Root reserves of South African Highveld grasses in relation to fertilizing and frequency of clipping. Journal of South African Botany 10, 37-54.
- WEINMANN H 1948a. Underground development and reserves in grasses. Journal of the British Grassland Society 3, 115-140.
- WEINMANN H 1948b. Effects of grazing intensity and fertilizer treatment on Transvaal Highveld. Empire Journal of Experimental Agriculture 16, 111-118.
- WEINMANN H 1955. The chemistry and physiology of grasses. In: Meredith D (ed) Grasses and Pastures of South Africa. Central News Agency Limited, Johannesburg, pp 571-600.
- WEINMANN H 1969. Effects of defoliation on veld and pastures. Proceedings of the Veld Management Conference, 29-38.
- WEINMANN H and REINHOLD L 1946. Reserve carbohydrates in South African grasses. Journal of South African Botany 12, 57-73.
- WEISSER P J 1978. Changes in areas of grasslands on the dunes between Richards Bay and the Mfolozi River, 1937 to 1974. Proceedings of the Grassland Society of Southern Africa 13, 95-97.
- WELLS M J 1959. An account of the plant ecology of the Nagle Dam area of Natal. MSc thesis, University of Natal.
- WERGER M J A 1973a. An account of the communities of "Tusse-a-die-riviere" game farm, Orange Free State. Bothalia 11, 165-176.
- WERGER M J A 1973b. Phytosociology of the upper Orange River valley, South Africa - a syntaxonomical and synecological study. PhD thesis, Catholic University, Nijmegen.

WERGER M J A 1978. Biogeographical division of southern Africa. In: Werger M J A (ed) Biogeography and ecology of southern Africa. Junk, The Hague, pp 145-170.

WERGER M J A 1983. Man's impact on vegetation. W Holner, M J A Werger and I Ikusima eds. Junk, The Hague.

WERGER M J A and COETZEE B J 1978. The Sudano-Zambezi Region. In: Werger M J A (ed) Biogeography and Ecology of southern Africa. Junk, The Hague, pp 301-462.

WEST O 1936. An investigation of the methods of botanical analysis of pasture. South African Journal of Science 33, 501-559.

WEST O 1951. The vegetation of Weenen County, Natal. Memoirs of the Botanical Survey of South Africa 23, 183 pp.

WEST O 1965. Fire in vegetation and its use in pasture management. Commonwealth Agricultural Bureaux, England. 53 pp.

WESTFALL R H, EVERSON C S and EVERSON T M 1983. The vegetation of the protected plots at Thabamhlope Research Station. South African Journal of Botany 2, 15-25.

WHITE F 1978. The Afromontane region. In: Werger M J A (ed) Biogeography and Ecology of southern Africa. Junk, The Hague, pp 463-513.

WHITE R E and GROSSMAN D 1972. The effect of prolonged seasonal burning on soil fertility under Trachypogon - other species of grassland at Frankenwald. South African Journal of Science 68, 234-239.

WICHT C L 1949. Forestry and water supplies in South Africa. Department of Forestry, Bulletin 33, Pretoria.

WICHT C L 1959. The management of water catchments. African Soils 4, 20-51.

WICHT C L 1971. The influence of vegetation in South African mountain catchments on water supplied. South African Journal of Science 67, 201-209.

WILTSHIRE G H 1972. Response of Highveld grass species to ammonium and nitrate nitrogen. Proceedings of the Grassland Society of Southern Africa 7, 67-75.

WILTSHIRE G H 1973. The response of grasses to nitrogen source. Journal of Applied Ecology 10, 429-435.

WISEMAN I G, NATHANSON K and GRAVEN E H 1972. Effects of phosphate carrier, phosphorus placement and level of lime application on plant growth on two oxisols in Natal. Proceedings of the Grassland Society of Southern Africa 7, 105-111.

WOLFSON M M, AMORY A M and CRESSWELL C F 1982. The effect of night temperature and leaf inorganic nitrogen status of the C₄ pathway enzymes in selected C₄ photosynthetic grasses. Proceedings of the Grassland Society of Southern Africa 17, 106-111.

WOODS D B and MOLL E J 1967. Multivariate analysis of grassland in the Three Rivers area, Natal. Proceedings of the Grassland Society of Southern Africa 2, 103-111.

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