A description of the Grassland Biome Project

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PREFACE

The National Programme for Environmental Sciences is a cooperative undertaking of scientists and scientific institutions in South Africa concerned with research related to environmental problems. The National Programme includes major research activities in inland water and terrestrial ecosystems, in all aspects of nature conservation and in the field of human needs, resources and the environment.

The Committee for Terrestrial Ecosystems has developed its programme within the five major biomes of South Africa - fynbos, karoo, grassland, savanna and forest. In each of these systems research designed to develop a predictive understanding of their structure and functioning is being coordinated within both site specific and extensive research projects.

The Grassland Biome Project has recently been initiated to coordinate existing and stimulate new research on the grasslands of South Africa. The valuable body of information developed during the last half century by range and pasture scientists will serve as a base from which new work will be initiated in order to fill gaps in our understanding of significant components and processes. While most of the work to be undertaken will be financed by participating organizations, research by universities and other independent research groups will be supported by the National Committee for Environmental Sciences from funds contributed largely by the Department of Environment Affairs.

ABSTRACT

The objectives, organization and research programme of the Grassland Biome Project are described against a background of the biome's ecological characteristics and environmental problems. Four principal research topics will be focused upon: (i) the definition and description of the grassland biome; (ii) ecosystem processes within the biome; (iii) dynamics within and between the biome and adjoining biomes and (iv) management and utilization of grassland ecosystems.

SAMEVATTING

Die doelstellings, organisasie en navorsingsprogram van die Grasveldbioomprojek word beskryf in die lig van die bioom se ekologiese eienskappe en omgewingsprobleme. Vier hoofnavorsingsonderwerpe word beklemtoon: (i) die definisie en beskrywing van die grasveldbioom; (ii) ekosisteemprosesse binne die bioom; (iii) dinamika binne en tussen die bioom en aangrensende biome en (iv) bestuur en benutting van grasveld-ekosisteme.

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INTRODUCTION

The grasslands of South Africa occupy approximately 27% of the country, predominantly on the highveld, escarpment and seaboard hills. The grassland biome supports a major portion of the country's maize, dairy, beef and timber industry while it is furthermore occupied by the country's industrial and mining centre.

Intensive agricultural practices and the effect of urbanization and industrialization have had a profound negative influence on the condition and stability of grassland ecosystems. The consequences of the rapidly deteriorating quality of grassland ecosystems have led to considerable concern amongst decision-makers and the Grassland Biome Project has recently been initiated to integrate efforts to develop the knowledge, understanding and expertise required to predict the outcome of available grassland management options.

Background to the study and a brief synopsis of the project's objectives and research approach are presented in this document. A more detailed description of the programme will be published at the conclusion of the first phase, which aims at the production of an overall synthesis of available findings from South African research activity, an annotated bibliography and the preparation of the present descriptive document and its distribution to potential project participants.

ECOLOGICAL CHARACTERISTICS

Distribution

For purposes of the proposed project, the geographical boundaries of the grassland biome have been based on Acocks (1975). In essence this means that the biome occupies grassy vegetation in the eastern portion of the country (Figure 1). In terms of the traditional view of Acocks, three major subdivisions exist:

(1) In the west of the biome are the so-called climatic climax or 'pure' grasslands. Excluded from this group is the False Upper Karoo (Acocks's Veld Type number 36). Formerly this Veld Type was Dry *Cymbopogon-Themeda* Veld (Acocks's Veld Type number 50). However, the False Upper Karoo has been included within the area of activity of the Karoo Biome Project. In an ecological context, therefore, there is overlap between the Karoo and Grassland Biome Projects, and researchers interested in arid grasslands should refer to the descriptions of both projects.

(2) In the humid eastern portions of the grassland biome are fire climax or false grasslands which are seral to forest.

(3) Also in the east of the biome is a second category of fire climax, or false grasslands, but in this case seral to bushveld or savanna.

Climate

The main features of the climate of this region are described by Schulze and McGee (1978). The January mean daily maximum temperature ranges from about 25°C in the south to about 30°C in the northwest of the biome. The July mean daily minimum temperature on the coastal hinterland in the east is about 10°C, but inland declines to less than 0°C. Frost is occasional and light in the subtropical coastal regions in the east and ranges to very severe in the sub-alpine zone. Rain falls mostly in summer (October to March), but is better distributed along the coast and in the south. The mean annual precipitation is lowest in the west (about 400 mm), and generally increases eastward to about 1000 mm along most of the coast. However, local differences are extreme, with up to 2000 mm on the slopes of the Natal Drakensberg, and less than 600 mm in the centre of the Tugela Basin.

A marginal (less than 100 mm) to moderate (200-400 mm) average annual water surplus is experienced during the period December to April. The average annual water deficiency throughout most of the grassland biome is less than 100 mm. These surpluses and deficiencies are calculated on the basis of monthly moisture balances. In the grassland biome the surpluses are generally greater and the deficiencies smaller than elsewhere in South Africa.

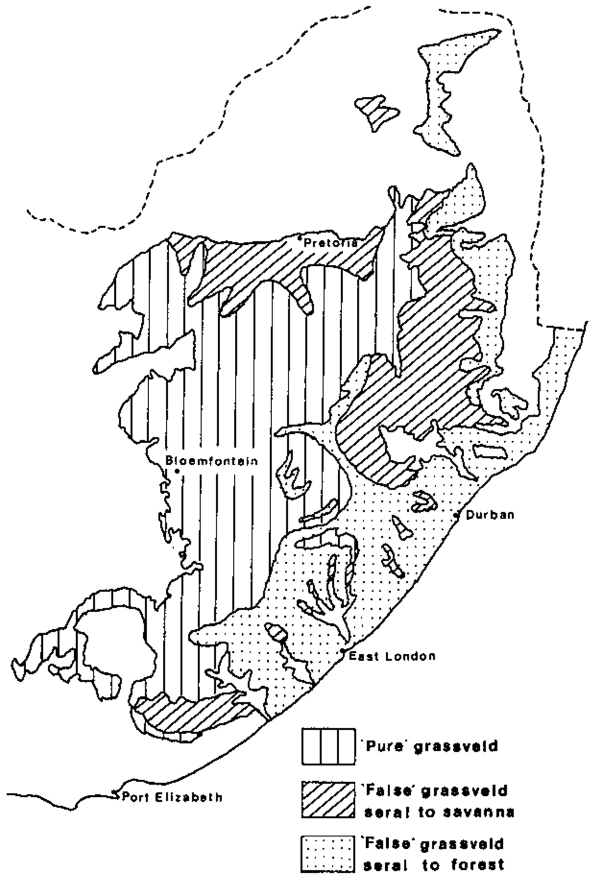

Figure 1. The major vegetational divisions of the grassland biome

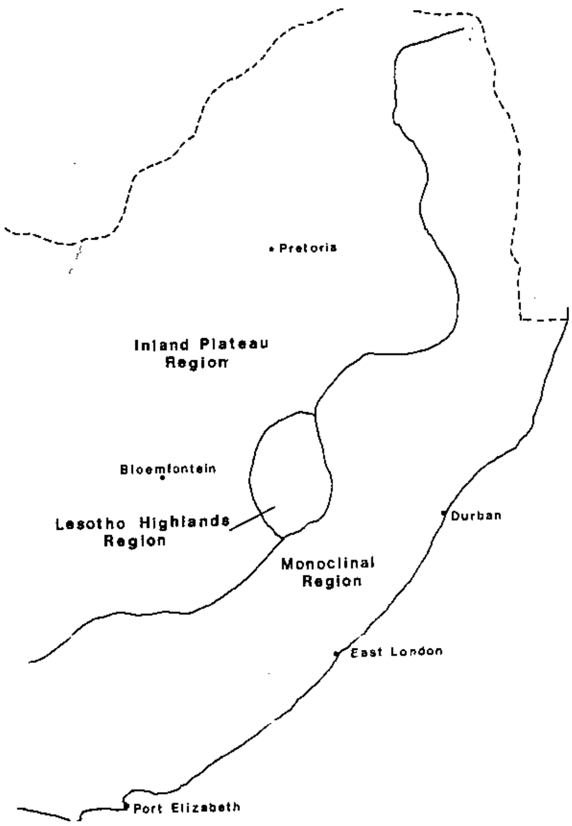

Figure 2. The physiographic regions of the grassland biome

Geology, topography and soils

Most of the grassland biome overlies rocks of the Karoo System. Older rocks are exposed along the northwestern to northeastern fringe, and along the axis of the Natal monocline. Post-Karoo strata exist only as Recent sands along the eastern coastal strip. Geomorphologically and topographically, the grassland biome consists of three main regions (Figure 2). Firstly, there are the Lesotho highlands, rising over 3300 m above sea level, comprising the Gondwana and Post-Gondwana bevels. These ancient landsurfaces are relics that predate and immediately follow the formation of the African continent. Secondly, there is a belt up to about 250 km wide along the eastern region which is discontinuously occupied by grassland. This zone consists of a monocline with land sloping steeply seawards, and deeply incised. The landsurfaces range from mid-Cretaceous (100 million years ago) to Recent. Thirdly, to the west of the abrupt and scarped western boundary of the monoclinal zone is the inland plateau region or highveld consisting of smoothly planed or gently rolling landsurfaces of Tertiary and Miocene age. Most of this land lies between 1000 m and 1800 m above sea level.

The soils of the monoclinal region are heterogeneous because of the localized differences in topography, parent material and weathering processes. Along most of the coast are dystrophic sandy soils. The inland, low-lying landsurfaces are young, warm and dry and eutrophic. On the elevated interfluves and other relics of old landsurfaces, precipitation is high, temperatures low and the consequent leaching processes extreme so that soils are dystrophic. Exceptions do occur. For example, there are eutrophic, black turf soils on the Stormberg Plateau. In the second region, the Lesotho highlands, soils are generally dystrophic. For the third region, the inland plateau, the soils in the west are eutrophic, weathering processes being modest. Eastwards there are pockets of eutrophic, black turf soils in a generally mesotrophic situation; eutrophic soils tend to occur only on promontories particularly on the eastern boundary.

Biota

Over most of the grassland biome the flora is dominated by C_4 grasses of tropical and sub-tropical affinities. However, for the Lesotho highlands and their immediate surrounds (especially southwards on the mountains of the eastern Cape) temperate C_3 grasses increase in importance with elevation. Traditionally, pastoralists have distinguished between 'sour' and 'sweet' grasslands. Sour grasses deteriorate significantly in nutritive value as they mature and at the onset of the dormant winter season. Sweet grasses tend to maintain their nutritive value. Gradients of sourness and sweetness broadly follow the dystrophy-eutrophy axes described above. While some grass species are diagnostic (eg *Monocymbium ceresiiforme* is a sourveld species, and *Panicum maximum* a sweetveld species), other grasses (eg *Themeda triandra*) occur along the entire sweet-sour gradient. The density of the sward ranges from about 10% in well-managed arid grassland to over 15% in the humid regions. Except for the grasslands of the potential savanna areas and potential coast forest, sward height is short, and mostly less than 0,5 m.

In the grassland areas seral to forest, woody vegetation is confined largely to sites sheltered from fire, and where fires are absent, infrequent or burn with low intensity. The lowland forests are relatively tall (20-35 m) and with Guineo-Congolian affinities. The midland and highland forests are short (10-25 m) and are related to the Afromontane Region. Particularly in the midland and highland areas, a fynbos element occurs as part of the forest precursor scrub.

Estimates of the vegetation potential on a biome-wide basis are available from two sources, namely Acocks (1975: Map 1) and Schulze and McGee (1978: Figure 12 and Table 2). Acocks's Map 1 is derived on the basis of Clementsian ecology where the believed climatic climaxes are identified. The portion of the grassland biome occupying the highveld and the Lesotho highlands are regarded by Acocks as pure grasslands where the potential set by the climate permits the vegetation to develop no further than a grassland. With a few minor exceptions, Acocks regarded the grassland of the monoclinal zone as seral to forest or scrub-forest. Acocks further proposed that the climatic climax vegetation existed as such 600 years BP. Schulze and McGee (1978) derived Holdridge Life Zones. These do not accord with Acocks's view in the respect that throughout the grassland biome the potential exists (in terms of the Holdridge classification) for forest, ranging from wet, through moist to dry. In the light of studies conducted since Acocks's initial proposal in 1953, several of his views are no longer tenable.

Firstly, much of the present grassland in the monoclinal zone has probably been grassland for a long time. Recurrent fire, initiated by lightning and other natural agents, has probably been a factor in local vegetation since long before hominids appeared, and favours the grasses rather than woody plants. The deep, humic A horizons (up to one metre or more in depth) of soils on the interfluves in the Natal coastal hinterland are believed to develop only under grass at relatively high altitudes. Remains of typically grassland animals have been excavated from the floor deposits of caves in Natal, and have been dated as far back as 8000 years BP. It is remarkable if not incongruous that such typically grassland animals as redwing francolin have their distribution centred in what Acocks regarded as forest or scrub-forest only 600 years ago. Doubtless, forest-boundaries have advanced and retreated during recent geological time, but it seems difficult to conceive that forest was ever continuous even during the coldest, wettest periods. Any theory about recent continuous forest faces the difficulty of explaining the widespread almost ubiquitous distribution of *Themeda triandra*, a grass with poor powers of dispersal.

Secondly, the upper montane and sub-alpine regions of Lesotho, Natal and the eastern Cape can support a heath which classically would be considered as a higher seral stage than grassland.

Thirdly, on the highveld, grassland withdrawn from grazing and fire tends to become moribund rather than advance in successional status to a woody community. This should, however, not be seen as necessarily climatically determined. Given a source of seed, and usually with a disturbance to the soil drainage pattern, woody plants grow. Topographic breaks relatively protected from fire are characterized by woody vegetation.

In a sense then, it is ironical that the grassland biome contains no 'pure' grassland. Were it not for fire, and perhaps grazing as well, the grasslands would not exist. The relative importance of these two defoliating agents varies across the grassland biome. In the sour grasslands, where primary production is high, grazing appears (except very recently) to have been no more than modest, and fires frequent and intense. At the other extreme, in the sweet grasslands, grazing has possibly been more important, at least relative to the amount of primary production, and fire probably of sporadic occurrence following seasons of exceptionally high precipitation.

Regarding the fauna, a rich and spectacular ungulate assemblage occurred formerly. There were animals of both localized (eg grey rhebuck, common reedbuck, mountain reedbuck and oribi) and migratory (eg black wildebeest, blesbok, red hartebeest and springbok) habit. The formerly vast herds of the latter group existed up until the late nineteenth century. Between 1870 and 1880 nearly 2 million "buck skins" passed through Durban harbour, but by 1890 game products ceased to be of economic importance, presumably because the resource had been exploited to near extinction. It is unfortunate that the animal component of this natural system was destroyed without being well described. All that remains are isolated, now resident herds of antelope, anecdotes from the past, and a simulation with domestic livestock of the former migrations from highveld in summer to lowveld in winter. Nevertheless, it has been argued that the rotational grazing systems applied with cattle and sheep today are a better simulation of past grazing patterns than are the confined, continuous grazing systems of both the pioneer pastoralists and present game managers.

The grassland avifauna lacks the diversity of the savanna, but there are some 21 endemic species, including 'threatened' species such as bald ibis, crowned crane, blue korhaan, ground woodpecker, Botha's lark and Rudd's lark.

Veld Types

Table 1 provides a list of Veld Types, as recognized by Acocks (1975), comprising the currently defined grassland biome. The extent of each Veld Type is indicated, as are the percentage contributions by each type to the total area of 351 814 km^2 of the biome. In terms of extent, the most important veld types are the Dry *Cymbopogon-Themeda* Veld (50), the *Cymbopogon-Themeda* Veld (48), and the Highland Sourveld and Dohne Sourveld (44). But perhaps more critical than relative area is the vulnerability of the Veld Types to change. In a sense, the entire biome is vulnerable since ecological succession has been arrested by periodic burning and grazing. It might be expected that changes in the defoliation regime would sensitively affect the state of the system. This is particularly so at the periphery of the biome, in what have been called the 'tension zones'.

TABLE 1. A grouping and listing of Veld Types, as recognized by Acocks (1975), and the extent of each type as supplied by the Botanical Research Institute (J C Scheepers, unpublished data 1982).

Number	Veld type Name	Extent (km^2)	% of biome
"Pure" grasslands			
22	Invasion of Grassland by Thorn	4 622,3	1,31
41	Pan Turf Veld invaded by Karoo	1 217,5	0,35
42	Karoid Merxmuellera Mountain Veld	2 258,7	0,64
48	Cymbopogon-Themeda Veld	37 531,6	10,67
49	Transitional Cymbopogon-Themeda Veld	17 147,3	4,87
50	Dry Combopogon-Themeda Veld	47 071,5	13,38
51	Pan Turf Veld	2 257,8	0,78
52	Themeda Veld or Turf Highveld	10 797,9	3,07
53	Patchy Highveld to Cymbopogon-Themeda Veld Transition	12 115,1	3,44
54	Turf Highveld to Highland Sourveld Transition	2 902,4	0,82
55	Bankenveld to Turf Highveld Transition	629,1	0,18
56	Highland Sourveld to Cymbopogon-Themeda Veld Transition	9 899,8	2,81
57	North-Eastern Sandy Highveld	14 752,0	4,19
58	Themeda-Festuca Alpine Veld	9 800,8	2,79
59	Stormberg Plateau Sweetveld	2 567,2	0,73
60	Karoid Merxmuellera Mountain Veld	15 223,2	4,33
Sub-total		191 294,2	54,37

TABLE 1. (continued)

Number	Veld type Name	Extent (km^2)	% of biome
Grasslands seral to forest			
1	Coastal Forest and Thornveld	26 399,5	7,5
3	Pondoland Coastal Plateau Sourveld	833,1	0,24
5	'Ngongoni Veld	11 965,8	3,4
8	North-Eastern Mountain Sourveld	9 528,4	2,71
44	Highland Sourveld and Dohne Sourveld	31 737,8	9,02
45	Natal Mist Belt 'Ngongoni Veld	3 944,8	1,12
Sub-total		84 409,0	24,0
Grasslands seral to savanna			
21	False Thornveld of Eastern Cape	3 891,3	1,11
61	Bankenveld	30 033,6	8,54
62	Bankenveld to Sour Sandveld Transition	1 519,4	0,43
63	Piet Retief Sourveld	7 888,3	2,24
64	Northern Tall Grassveld	5 405,8	1,54
65	Southern Tall Grassveld	18 437,4	5,24
66	Natal Sour Sandveld	5 771,6	1,64
67	Pietersburg Plateau False Grassveld	2 489,9	0,71
68	Eastern Province Grassveld	673,3	0,19
Sub-total		76 110,8	21,63
Grand total		351 814,4	100,0

ENVIRONMENTAL PROBLEMS

Situation and projections

The grassland biome makes up about 29% of the total of 1220 000 km^2 of South Africa. It is climatically hospitable and agriculturally the most productive biome in South Africa, contributing overwhelmingly to the country's gross annual production of approximately R1,3 billion for maize, R228 million for fresh milk, R145 million for other dairy products, R625 million for beef, and in excess of 4,5 billion m^3 of sawlogs. It happens also to contain the overwhelming majority of people in South Africa. This arises not only because of its agricultural potential, but also because of the discovery within it of large coal deposits and the world's richest goldfields. This coincidence of agricultural, fossil-fuel and mineral wealth and the attendant economic growth, industrialization and westernization of African peoples is not without serious environmental repercussions and potential resource deficiences.

Table 2 compares world and South African figures for present and projected populations, land areas available, areas of arable and presently cultivated land, and present and projected amounts of cultivated land per person. The figures come from various sources and of course are open to criticism. However, no amount of informed criticism alters four salient conclusions. Firstly, South Africa is poorly endowed with arable land. Secondly, most of this arable land is already cultivated. Thirdly, whatever currently arable but non-cultivated land is ploughed in the future will unlikely compensate for losses via urbanization and industrialization and will displace the present form of use. Fourthly, by virtue of the rate of population growth being higher in South Africa than for the world as a whole (2,6% vs 1,9% per year), South Africans will have less cultivated land per person at the turn of the century than is now available to the average person on this globe. For what it might be worth, the United Nations average minimum of cultivated land to support a person adequately is 0,4 ha. With up to half the present world population (depending on whose estimates are used) under- or malnourished, it is sobering to contemplate the future. On current projections, South Africa will, within the lifetimes of most who read this document, plummet from the present position of affluence to one of extreme resource competition, or poverty.

A second fundamental resource which is scarce is water. The estimated average annual runoff of water in South Africa is 52 km^3, equivalent to a sheet of water only 4,3 cm in depth spread over 122 million ha. The gross annual availability of water on a per capita basis is only 1857 m^3 $person^{-1}$ - one half of that available to the average Eurasian, and one twelfth of that available to the average Australian. As a crude estimate, 67% of South Africa's runoff comes from the less than one third of the area contributed by the grassland biome. The Rand Water Board, responsible for supplying water to the 1713 200 ha Vaal triangle occupied by 5 million people and providing 60% of the country's manufacturing production, had in 1978 a capacity to deliver 2 245 million l day^{-1}. The projected need for the year 2000 is 8400 million l day^{-1} of which only 6600 million l day^{-1} can be obtained locally. The deficit must be supplied from distant catchments (eg the Tugela-Vaal scheme).

TABLE 2. Comparative figures for the world and South Africa on population size, land area available, extent of cultivated land, and extrapolations.

		World	South Africa
Population size (millions)	1980	4 000	28
	2000	6 000	50
Land area (million ha)		14 900	122
Arable land (million ha)		3 190	18,3
(% of total)		21	15
Cultivated land (million ha)		1 389	16
(% of arable)		43	87
Cultivated land (ha $person^{-1}$)	1980	0,35	0,57
	2000	0,23	0,32

Soil erosion

The scarcity of these resources of high quality land and water are aggravated by resource depletion. First is the physical loss of soil.

An estimated 400 million tons of sediment are delivered annually into the sea by the country's rivers. This is equivalent to 3,3 t lost from each hectare each year - somewhat in excess of an order of magnitude figure of 1 t ha^{-1} a^{-1} for the rate of soil genesis. There are many figures which illustrate the highly localized nature of soil erosion. Losses tend to be greatest on many of the areas of land most intensively used for agricultural production. But, by and large, detailed figures are not necessary to drive home the point. The average rate of soil genesis amounts to the addition of a layer of soil about 0,1 mm deep per year. Thus, where soil loss is detectable by the unaided eye, the loss is excessive. There are few vistas obtainable in the grassland biome which do not offend this unaided eye.

Vegetation change

The second aspect of resource depletion is more grave than the first. Soil erosion is said to be an insidious process. It has been and still is an emotive topic. It has attracted attention, although evidently insufficient remedial action. However, it is but an extreme symptom of a pervasive degradative process involving changes to vegetation on a grand scale. Acocks (1975) wrote in 1953 that 'The development of (the False Upper Karoo) constitutes the most spectacular of all changes in the vegetation of South Africa. The conversion of 51 800 km^2 of grassveld (Dry Cymbopogon-Themeda Veld) into eroded Karoo can only be regarded as a national disaster'. Over the past 30 years the karoo has continued to advance eastwards.

Eastward invasion into the grassland by Karoo is not the only vegetation change, and indeed the response of veld to overuse varies across the biome. Sweet grasslands have suffered a breakdown in the cover of tufted perennial grasses, ie denudation. Invasion by savanna or karoid species, or both, most of which are resistant to heavy animal use by virtue of their woodiness, spininess or toxicity, has been insufficient to protect the soil from spectacular erosion.

Interestingly, this fragility of our semi-arid areas coincides with experience elsewhere. Under extremely arid conditions, not experienced in the grassland biome, the erosivity of rainfall is so low that there is little energy to move soil even in the absence of plant cover. Under humid conditions, although the erosivity may be extreme, the moisture regime sustains a dense protective cover over the soil. In the intermediate or semi-arid situation (the 'tension zones' of the grassland biome) the moisture status is insufficient to sustain plants subjected to heavy or frequent defoliation, but the rainfall erosivity is sufficient to move soil which is often highly erodible anyway. However, it should not be thought that the sour grasslands of the humid regions of the grassland biome have remained unchanged since European settlement. Moderately palatable tufted perennial grasses, of which Themeda triandra is the foremost, have been replaced by highly competitive unpalatable grasses of similar growth form. The primary causes of change have been excessive and selective defoliation. The common invaders are comprised of 'mtshiki' and 'wire' grasses and a false fynbos element. The 'mtshiki' grasses (Eragrostis curvula, E plana, Sporobolus africanus and S pyramidalis) encroach under heavy grazing and trampling, and are also favoured by nitrogen enrichment. Fynbos is favoured by heavy grazing and the consequent scarcity of fuel to carry intense fire. The 'wire grasses' (Aristida junciformis, Diheteropogon filifolius, Elionurus muticus, Loudetia simplex and Rendlia altera) come to dominate under conditions of selective defoliation. Recent studies reveal also that Themeda triandra is extremely sensitive to fire once spring growth has been initiated and before winter dormancy occurs. It is likely therefore that the formerly popular autumn burning of veld, and the widely advocated late spring burning have contributed to the demise of valuable grazing land.

The situation in the upper montane and sub-alpine zones is also cause for concern. Traditionally, the grasslands here have been regarded as sweet. This is untrue in the eastern part of Acocks's Themeda-Festuca Alpine Veld where the average level of crude protein drops well below 4% on a dry mass basis in winter. However, westwards the rainfall and therefore the intensity of soil leaching decline, the black turf soils occur, and the proportion of palatable temperate grasses in the flora increases. However, not all temperate grasses are palatable, Merxmuellera disticha and Festuca costata being the common unpalatable invading grasses which are accompanied by a false karroid fynbos element (eg Felicia filifolia). Baring of the soil is not readily reversible because of the well-known inhospitability of high-mountain environments (viz intense insolation by day, rapid radiation of heat by night, extreme diurnal fluctuations in ground surface temperatures, and frequent frost heaving). These mountainous areas of course comprise the headwaters of many of the country's major rivers.

It may well be asked why veld has been overutilized. Perhaps there is no simple answer, but several factors can be mentioned. Firstly, it often pays - in the short term - to overgraze. This is particularly so in sour grassland. If the plants are allowed to mature, by infrequent or light defoliation, they lose quality, and animal performance declines. Even in sweet grassland this is relevant if, for example, animals which require a high quality intake (eg sheep) are being run. Hence, it is said, that much of the Dry Cymbopogon-Themeda Veld has been transformed to False Karoo because operators have their sheep graze camps frequently. Grass plants cannot survive this treatment where they are never permitted to grow out. The second factor applies mostly in the arid regions of the biome. The very erratic rainfall results in a high probability of graziers, unless they respond quickly to drought, overstocking their land in relation to the standing crop of herbage and its immediate vigour. Thirdly, once the veld composition has been altered in favour of unpalatable species, the grazier is inclined to stock heavily to prevent plants from maturing, and thereby minimize unpalatability. Whatever palatable and desirable components still occur are severely stressed so that veld rehabilitation cannot occur. Fourthly, a decline in the productive capacity of the veld, due to abusive practices, ultimately leads to poor animal performance and reduced economic returns. The operator then attempts cash-cropping, often in situations which are only marginally suited to such land use. A succession of 'bad' years leads to crop failures, and lands are withdrawn from cultivation. The secondary vegetation which establishes on the old lands is then often even poorer for animal production than the former degraded but virgin veld.

Another issue of growing concern is large-scale strip-mining, especially for coal, which is taking place in the grassland biome. It is possible, at some expense, to re-establish a vegetation cover to satisfy ideals of stability and aesthetics. But how might significant quantities of forage be produced? Another implication of the resort to fossil fuel is the expulsion of apparently large amounts of heavy metals (lead and mercury) from the giant coal-fired thermal generators on the eastern highveld. Although trace amounts of some heavy metals are necessary for life, excesses are highly toxic. For example, photosynthesis by phytoplankton is recognizably depressed by only 0,1 parts mercury per billion parts water. Higher plants are also affected, and concentrations of mercury tend to be amplified up food chains with deleterious consequences to consumers.

Veld rehabilitation

A variety of techniques - involving manipulation of the movements and stocking densities of livestock and of livestock ratios, the careful siting of fences, and the judicious use of fire - have been applied successfully in parts of the sweet grassland. The dramatic rehabilitation achieved by the Howells, the late Edgar Matthews, and others bear testimony to this. Improved understanding of the effects of the various strategies, and the individual responses of key species (both desirable and undesirable) will facilitate the sorely needed widespread application of these and other remedial measures.

In the sour grasslands and in the upper montane and sub-alpine zones the prospects of reversing the widespread floristic changes are challenging. In the eastern Cape, invasive fynbos (*Cliffortia linearifolia*, *C paucistaminea* and *Erica brownleeae*) has been controlled successfully by resting and burning of veld. Similar research and development of techniques is required on invasive fynbos in the Natal mistbelt, on the mountains near Vryheid, and in the Bankenveld. While the fynbos appears sensitive to frequent intense fire, and to a vigorous and competitive sward, rapid and inexpensive displacement of the invasive grasses is a refractive problem. The reasons for the tenacity of these plants are not clear. As already mentioned, farmers who use such degraded veld tend to stock heavily and graze frequently to prevent the plants from maturing and so maintain their acceptability to the animal. This precludes reoccupation by the desirable, palatable species, and in the extreme leads to their local extinction. Further, the capacity of *Themeda triandra* to reinvade areas from which it has been eradicated, is poor.

Firstly, and this is especially so in the low rainfall areas, its demise often occurs with substantial soil loss. The micro-environment is so altered as to no longer be hospitable to *Themeda triandra*. Secondly, the grass produces little seed, and seedlings are delicate, being easily tramped out or (in the moist regions) shaded out by the vigorous mtshiki and wiregrasses.

It can be stimulated to reproduce vegetatively by carefully timed winter and summer defoliations, but migration of the species by this means is inevitably a slow process. Also, where disturbance of the veld has been by nitrogen enrichment, *Themeda triandra* cannot survive or cannot compete with the 'mtshiki' species. Indeed, the competitive nature of the 'mtshiki' grasses under fertilized situations is a serious problem in attempts to reinforce or radically improve sour grassland. Additional factors might concern the relative abilities of individual species and ecotypes to tolerate certain soil conditions like high levels of aluminium. In general, then, the understanding of the properties of grassland ecosystems will be well served by autecological work on the key species.

Nature conservation

In the field of wildlife conservation, only about 1,5% of the grassland biome is included within designated national parks, provincial reserves and state forests (figures based on Edwards (1974)). With the Karoo and Karoid Bushveld, this represents the lowest level of 'designation' among the biomes of South Africa, and 18 of the 31 veld types listed in Table 1 are not represented in any designated area. Considerable additional acquisition of land is therefore necessary to provide representation of as yet unrepresented Veld Types, and to improve representation of most other Veld Types. A list of priority acquisitions is required to take account of the location of populations of endangered species, and the fact that certain Veld Types are seriously threatened by industrialization, urban expansion, radical veld improvement, afforestation and other factors. However, these measures alone are insufficient. Methods of developing appropriate management goals to perpetuate diverse and dynamic genetic reservoirs need to be refined, and the strategies (control over grazing, browsing and fire) to attain these goals need to be explored. Further, because of the extreme competition for land, and in view of current notions about island biogeography, whatever additional land becomes reserved solely for wildlife conservation, is bound to be woefully inadequate. Worse still, the practice of sheltering the gene pools within designated areas from the stresses and selection pressures that prevail over most of the country will, if anything, prejudice their adaptation to future conditions and therefore to long-term survival. A new strategy is required, one which extends consideration from its present focus on the 'islands' to the extensive 'oceans' in between. Effort needs to be directed at developing management strategies which promote and maintain species diversity and system resilience. Fundamental to this is a knowledge of the capacity of systems to absorb change in inputs and change in their states without 'flipping' into fundamentally different and undesirable modes of behaviour.

OBJECTIVE AND RESEARCH STRATEGY

The objective of the Grassland Biome Project is to develop an understanding of grassland structure and functioning necessary to enable the prediction of the effects of likely perturbations to grassland ecosystems.

The project will be aimed at complementing the activities of existing natural resource agencies in their management of and research on grassland resources for sustained human benefit, especially in the fields of livestock and water production, and wildlife conservation.

The research programme will include four interdependent components:

(i) The analysis, description and interpretation of the characteristics and distribution of grassland ecosystems across gradients of climate, geomorphology and soils within South Africa.

(ii) The detailed examination, via site-bound studies, of the structure and functioning of selected plant communities in terms of key components and processes (especially energy and water balances and nutrient cycling) and the influence of various forms of perturbation such as defoliation by herbivores and fire.

(iii) The examination of the dynamics within and between communities, and the manner in which the dynamics of communities is influenced by and responds to alterations in the abiotic and biotic environment.

(iv) An ongoing review of the problems relating to the management and utilization of grasslands for optimum forage, livestock and water production, and wildlife conservation.

Research activities will range from biome-wide surveys to site-bound process studies involving laboratory and field experiments. The success of the project will rest on the effective integration of research being undertaken at the universities and government research stations within the grassland biome.

1. Definition and description of the grassland biome

Rationale

A general description of the study area is required. The purpose is to identify and determine the location and extent of major types of grasslands within the biome. This will facilitate the planning and execution of research, and assist in determining to what extent research findings may be extrapolated geographically. Existing country-wide (eg Acocks 1975) and regional (eg Pentz 1945; Edwards 1967; Phillips 1973) surveys may serve as a basis for updating and refinement achieved with improved methods of data collection and processing.

Key questions

(i) What is the origin, location and extent of grassland and related transitional vegetation?

(ii) What are the main vegetation types and facies within the grassland biome, in terms of floristics and physiognomy?

(iii) What are the relationships between grassland types and soil nutrients, particularly in terms of so-called sweet and sour types?

(iv) How do the various grassland types relate to climatic factors, in particular to the water balance?

2. Ecosystem processes within the grassland biome

Rationale

Whatever properties an ecosystem has, depends on the nature and behaviour of its components. Complete knowledge of all the components and their interactions is neither possible nor necessary. But a knowledge of key components and how they interact and respond to important driving and state variables is within reach. Here the identity of key and important depends on the particular viewpoint of the system. The present viewpoint focuses attention on certain system outputs (eg forage and water production). It is therefore the components and variables which primarily determine these outputs that require attention. An intelligent guess at which the relevant issues are is possible from research and modelling efforts elsewhere. What is most deficient locally is the quantification of the variables. The key questions below are therefore arranged for a systematic build up of information from (a) the abiotic variables and the basic form and behaviour of important types of organisms, through (b) how individual organisms respond to changes in the abiotic and biotic variables, and (c) how communities respond to changes in the abiotic and biotic variables to (d) how community changes interactively modify the state and behaviour of the system.

Key questions

(i) What are the spatial and temporal variations in the driving variables of insolation, temperature and moisture, and what are the effects of these on soil water and nutrient budgets?

(ii) How are the morphology, phenology and physiology of individual important plants and animals related to spatial and temporal changes in the abiotic variables of insolation, temperature, moisture and nutrients?

(iii) What are the community responses (specifically those which materially affect the already identified important system outputs) to the abiotic variables, and to spatial and temporal variations in them?

(iv) How are the basic patterns under question (ii) modified by variations in the defoliation regime (including effects of removal of underground plant parts)?

(v) How are the responses under question (iii) modified by variations in the defoliation regime?

(vi) What roles do fire, herbivory, copraphagy and decomposition play in modifying the soil water and nutrient budgets?

(vii) What and how do abiotic factors (eg insolation, temperature, moisture, wind, soil nutrients) and biotic factors (eg quantity and quality of live or dead organic matter) affect rates or intensities of fire, herbivory, copraphagy and decomposition?

3. Dynamics

Rationale

It is clear that considerable changes have occurred in the grassland biome since European settlement (see ENVIRONMENTAL PROBLEMS). The changes which affect the system outputs on which attention has already been focused are of particular importance. These changes and their causes need to be identified and described in terms of geographical location and rate and nature of change. The specific kinds of change of greatest interest are those which relate to forage production, water production, soil erosion and system resilience.

Key questions

(i) What changes are taking place between the grassland and other biomes?

(ii) What changes are taking place within the grassland biome?

(iii) At what rates are these changes occurring?

(iv) What are the major causes of the changes?

4. Management and utilization

Rationale

In order to develop and maintain a realistic viewpoint of the Grassland Biome Project it is necessary to know how grassland resources are being used at present, what the projected patterns and intensities of use are, what problems exist at present, and what problems are likely to arise in the future. This knowledge acts as a starting point for developing options in resource allocations and management. These options may then be evaluated.

Key questions

(i) What are the current land use practices in the grassland biome?

(ii) What projections can be made about land use practices and the intensity of resource use?

(iii) What ecological limitations exist, and are likely to arise in the near future in regard to use of the resources?

(iv) What options exist in relation to allocating resources for different forms or combinations of land use, and in relation to managing resources (viz manipulation of fire, stocking rates, livestock ratios, mowing, fertilization, veld reinforcement, bush clearing, etc) to raise the level of forage and water production, and of conservation of soil and wildlife?

(v) What are the responses of grassland systems to these manipulations in terms of forage and water production, soil and wildlife conservation and resilience?

EXISTING RESEARCH PROJECTS IN THE GRASSLAND BIOME

The following is a listing of research projects currently being carried out in different parts of the grassland biome. The institutions involved are indicated.

University of the Orange Free State

1. The physical-chemical relationships in the reclamation of alkaline soils with iron sulphate. R du T Burger, Department of Soil Science.

2. Analysis of the climate and determination of the production potential of vegetation and veld and irrigation scheduling in the Orange Free State. J M de Jager, Department of Agrometeorology.

3. The introduction and optimal utilization of small-stock farming in an irrigation farming system. D P J Opperman and O B Kok, Department of Pasture Science.

4. Ecology of *Kipteria* in the western Free State pan areas. R van Pletzen, Department of Zoology.

5. Ecology of blood-feeding Dipotera of the western Free State pan areas. R van Pletzen, Department of Zoology.

6. Intake of water by higher plants. E M van Zinderen Bakker, Institute of Environmental Sciences.

7. Intake of phosphate by grass plants. E M van Zinderen Bakker, Institute of Environmental Sciences.

8. Determination of primary production of higher plants. E M van Zinderen Bakker, Institute of Environmental Sciences.

9. Monitoring of the production capacity of and successional changes in various main veld types of the Eastern Cape Agricultural Region. L F Vorster, Department of Pasture Science.

University of the Witwatersrand

10. An investigation into the regulation of photosynthetic activity and starch content in *Panicum maximum* in relation to nitrogen and phosphorus nutrition. C F Cresswell, Department of Botany and Microbiology.

11. Influence of nitrogen supply on growth rate, photosynthetic activity and nitrogen metabolism of *Digitaria eriantha* var *smutsii*. C F Cresswell, Department of Botany and Microbiology.

12. A classification of selected C_4 photosynthetic plants on the basis of initial products, and decarboxylating enzymes as outlined by Hatch, Kagawa, Craig (1975) when grown under varying nitrogen conditions. C F Cresswell, Department of Botany and Microbiology.

13. Effect of temperature on the ratio of RuBPC PEPC in C_3 and C_4 plants. C F Cresswell, Department of Botany and Microbiology.

14. Effects of changing light intensity, oxygen and nitrogen concentration on the $^{12}C/^{13}C$ ratio in the photosynthetic intermediates of C_3, C_4 and CAM plants. C F Cresswell, Department of Botany and Microbiology.

15. Distribution of photosynthetic intermediates of C_3 and C_4 photosynthetic plant leaves by thin section micro-autoradiography. C F Cresswell, Department of Botany and Microbiology.

16. A study of the amino acid composition of leaf, stem, and root tissue of selected C_4 and C_3 plants, grown in the presence of (i) nitrate and (ii) ammonium nitrogen at the following concentrations: (1) 50 mg l^{-1}; (2) 200 mg l^{-1} and (3) 400 mg l^{-1}. C F Cresswell, Department of Botany and Microbiology.

17. The influence of light intensity and temperature on the photosynthetic rate, "Warburg Effect" and carbon dioxide compensation point of selected C_3 and C_4 photosynthetic plants grown in the presence of (i) nitrate and (ii) ammonium nitrogen at the following concentrations: (1) 50 mg l^{-1}; (2) 200 mg l^{-1} and (3) 400 mg l^{-1}. C F Cresswell, Department of Botany and Microbiology.

18. An investigation into the assimilation and translocation of nitrate, and ammonium nitrogen in roots, stems, and leaves of C_3 and C_4 photosynthetic plants. C F Cresswell, Department of Botany and Microbiology.

19. The effect of nitrogen concentration, and form on photosynthetic rate, carbon dioxide compensation point and photosynthetic metabolism of <u>Alloteropsis semialata</u>, which exhibit Kranz and non-Kranz anatomy. C F Cresswell, Department of Botany and Microbiology.

<u>University of Pretoria</u>

20. A comparison of grazing and forage types and combinations of these for animal production by beef bullocks. J O Grunow, Department of Plant Production.

21. Comparison of <u>Eragrostis curvula</u> cultivar Ermelo with other cultivar types on two different localities. J O Grunow, Department of Plant Production.

22. Investigation of the nutrient requirements of <u>Digitaria eriantha</u> and its reaction to defoliation. J O Grunow, Department of Plant Production.

University of Natal

23. Long-term veld mowing and burning trial. N M Tainton, Department of Pasture Science.

24. Long-term effects of the system of grazing management and of stocking rate on veld composition and yield. N M Tainton, Department of Pasture Science.

25. Long-term effects of the periods of occupation and absence on veld composition and yield. N M Tainton, Department of Pasture Science.

26. Long-term veld fertilizer trial. N M Tainton, Department of Pasture Science.

27. Simulation of grazing of moist tall grassveld. M T Mentis, Department of Pasture Science.

28. Characterization of growth curves of veld in moist tall grassveld. J R Klug, Department of Pasture Science.

29. Ecological studies of the grasslands on the eastern shores of Lake St Lucia. D E Conlong, Department of Botany.

30. Nondestructive fuel measurement of leaf water potential using thermocouple hydrometers. M J Savage, Department of Soil Science and Agrometeorology.

31. Complete revision of rainfall maps for southern Africa: mean annual, mean monthly variability and rainfall regions. R E Schulze, Agricultural Catchment Research Unit.

32. Study of soil moisture deficits in southern Africa: duration of deficits, intensity of deficits and probability of deficits. R E Schulze, Agricultural Catchment Research Unit.

33. Study of rainfall erosivity in southern Africa. R E Schulze, Agricultural Catchment Research Unit.

34. A preliminary survey of small mammals in the Kenneth Stainbank Nature Reserve. J A J Meester, Department of Biological Sciences.

University of Durban-Westville

35. Runoff and throughflow estimates under different defoliation treatments in grassland at Westville. H Watson and G du T de Villiers.

University of Fort Hare

36. Veld rehabilitation and management studies in the Ciskei. W S W Trollope, Department of Agronomy.

Nature Conservation Division of the Orange Free State

37. The Plant ecology of the Willem Pretorius Game Reserve. D B Muller.

38. The status distribution and habitat requirements of the grey rhebuck (*Pelea capriolus*) in the Orange Free State. N A Ferreira

39. Comparative production and condition of black wildebeest (*Connochaetes gnu*) in the Orange Free State with emphasis on the interaction between habitat and the animal density. S Vrahimis.

Department of Agriculture: Natal Region

40. Strip replacement of ngoni veld in bioclimates. P J Edwards.

41. Beef steers grazing sandy sourveld at six stocking rates. P J Edwards.

42. Fertilization of old lands under grazing.

43. Evaluation of veld potential with beef animals. P J Edwards.

44. Veld burning and mowing in bioclimate 4E. P J Edwards.

45. Regrowth rates of veld burned at various times in spring. P J Edwards.

46. Soil-inhabiting insects damaging veld.

Department of Agriculture: Transvaal Region

47. Fertilization of northeastern sandy Highveld. N F G Rethman.

48. Fertilization of northeastern montane sourveld. N F G Rethman.

49. Influence of fertilization and paraquat on the winter nutrient value of veld. N F G Rethman.

50. Veld observation of selection patterns of grazing animals on sourveld in the southeastern Transvaal. J J Odendaal.

51. Osophageal fistula-sample investigation of plant species selection of sourveld in the southeastern Transvaal. J J Odendaal.

52. Introduction of rhizome grass in the sourveld of the southeastern Transvaal. N F G Rethman.

53. Introduction of Kikuyu in the sourveld of the southeastern Transvaal. N F G Rethman.

54. Establishment of perennial legumes in the natural veld of the southeastern Transvaal. N F G Rethman.

55. Influence of winter defoliation of the grass covering of the sourveld of the southeastern Transvaal. N F G Rethman.

56. Development of a veld utilization system with the elimination of untimely fires for the extensive sour grassveld of the southeastern Transvaal. N F G Rethman.

57. Development of a practical, acceptable cattle farming system for the semi-extensive area of the southeastern Transvaal. N F G Rethman.

58. Growth and development of *Diheterogon amplectans* and *Eulalia villosa* in the southeastern Transvaal. N F G Rethman.

59. Comparison of *Vigna exillata* reinforced veld with natural veld for autumn grazing by sheep. N F G Rethman.

Department of Agriculture: Eastern Cape Region

60. Radical veld reinforcement: methods by which to control *Nasella* in the high-rainfall sourveld areas of the Eastern Cape. L O Nel.

61. Cultivated grazing: species with which to replace *Nasella* in the high-rainfall sourveld areas of the Eastern Cape. L O Nel.

62. Cultivated grazing: evaluation of grazing species for veld reinforcement in the high-rainfall sourveld areas of the Eastern Cape. T Daines.

63. Cultivated grazing: growth patterns of summer grasses in the high-rainfall sourveld areas of the Eastern Cape. T Daines.

64. Veld: growth and development of key grass species in the central grassland of the Eastern Cape. J Danckwerts.

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67. Veld: growth rate of key grass species in the central grassland areas of the Eastern Cape. J Danckwerts.

68. Veld: influence of season and plant age on the net assimilation rate of key grass species in the central grassland areas of the Eastern Cape. J Danckwerts.

69. Veld: development of a rewarding cattle farming system in the central grassland areas of the Eastern Cape. A Aucamp.

70. Veld: evaluation of the production potential of an Acacia/grass pasture in the central grassland areas of the Eastern Cape. A Aucamp.

71. Veld: influence of Acacia karroo on forage production in the central grassland areas of the Eastern Cape. A Aucamp.

72. Veld: preferential order and production of grasses in the central grassland areas of the Eastern Cape. A Aucamp.

73. Veld: dry matter yield and growth curves of various grasslands dominated by key species in the central grassland areas of the Eastern Cape. S Stuart-Hill.

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Department of Agriculture: new facets for registration

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National Parks Board

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83. Plant-sociological study of the National Highland Park. H J Venter.

84. Distribution and extension of Leucosidea sericea in Golden Gate Highland National Park. P T van der Walt.

85. Surveys of disease conditions, parasites and certain selected physiological values of wild animals in Golden Gate Highland National Park. V de Vos and I Horak.

86. A plant-sociological reconnaissance survey of the Golden Gate Highland National Park. P T van der Walt.

Department of Environment Affairs

87. Investigation of the plant communities and their controlling environmental factors in the Natal Drakensberg. J E Granger.

88. Description and classification of plant communities in Cathedral Peak experimental catchments, Natal Forest Region. D N S Tomlinson.

89. Investigation of the ecology of francolin populations on Highmoor State Forest and elsewhere on the Natal Drakensberg catchment. M T Mentis.

90. Interrelations of vegetation and eland in Giant's Castle Game Reserve. J S B Scotcher.

91. Study of the lammergeyer and Cape vulture in Natal and Lesotho Drakensberg. C J Brown.

92. Determination of the effects of veld-burning treatments on the major plant communities of the Natal Drakensberg catchment. F R Smith.

93. Experimental studies of the effects of controlled burning, protection and controlled summer grazing in highland sourveld and *Themeda-Festuca* alpine veld in gauged experimental catchments at Cathedral Peak Forestry Research Station. C Everson.

94. Experimental investigation of the effects of burning treatments on highland sourveld in replicated plot trials at selected centres in the Natal Drakensberg catchment. C Everson.

95. Synthesis of information on fire regime characteristics in the Natal Drakensberg. J E Granger.

96. A study of the weathering and other processes causing deterioration and the development of techniques to preserve the rock art in Natal Drakensberg. J H P van Aardt and P J Loubser.

ADMINISTRATION OF THE PROJECT

The Grassland Biome Project is one of several major cooperative inter-disciplinary studies being undertaken within the Terrestrial Ecosystems Section of the National Programme for Environmental Sciences.

The contributions of participating organizations, which include the Department of Environment Affairs, Department of Agriculture, the Division of Nature Conservation of the Orange Free State, the Natal Parks Board, the Universities of Natal, the Orange Free State, Fort Hare, Witwatersrand, Potchefstroom and Pretoria are coordinated by a Steering Committee appointed by the President of the CSIR.

The Steering Committee is responsible for the formulation and revision of the overall project plan, the evaluation of applications for funding, the presentation of recommendations for funding, the organization of appropriate symposia, workshops and seminars and the approval of final reports and manuscripts submitted for publication.

The Cooperative Scientific Programmes division of the CSIR provides both secretariat and programme management support. Funds for the research programme are provided from the budgets of individual participating organizations and from the central funds of the National Programme for Environmental Sciences provided mainly by the Department of Environment Affairs.

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