

Monitoring of the vegetation around artificial watering points (windmills) in the Kalahari Gemsbok National Park

N. VAN ROOYEN, D. BEZUIDENHOUT, G.K. THERON and J. DU P. BOTHMA

Van Rooyen, N., D. Bezuidenhout, G.K. Theron and J. du P. Bothma. 1990. Monitoring of the vegetation around artificial watering points (windmills) in the Kalahari Gemsbok National Park. - *Koedoe* 33(1): 63-88. Pretoria. ISSN 0075-6458.

Vegetation changes around artificial watering points were monitored in the Kalahari Gemsbok National Park from 1978 to 1989. Both rainfall and grazing influenced the vegetation but rainfall appeared to be the more significant factor. The above-average rainfall during the years preceding 1978 contributed to a relatively high basal cover in 1978. Since 1978, however, below-average rainfall was recorded resulting in a decline in basal cover, presence, frequency and density of most of the plant species. It seems likely that a wet cycle commenced in 1988, which is reflected in higher rainfall and an increase in basal cover, presence, and density. Some species maintained a relatively constant presence, some increased, and some declined during the study period. The monitoring is being continued.

Key words: Kalahari, monitoring, rainfall, vegetation.

N. van Rooyen, D. Bezuidenhout and G.K. Theron, Department of Botany, University of Pretoria; J. du P. Bothma, Centre for Wildlife Research, University of Pretoria, 0002 Republic of South Africa.

Introduction

Long-term vegetation change (succession) in semi-arid to arid areas is usually allogenic in response to geomorphological processes, and overgrazing and trampling may induce successional or degradational trends in arid communities such as in the southern Kalahari (Noy-Meir 1973; Werger & Leistner 1975). The vegetation of the Kalahari Gemsbok National Park (KGNP), being largely representative of the southern Kalahari in general, is protected from the over-utilization common in the adjacent farming areas and is well preserved (Leistner & Werger 1973; Werger 1978). However, over-utilized patches do occur around some watering points in the KGNP. Autogenic succession rarely occurs in the southern Kalahari (Werger & Leistner 1975), but fluctuations in rainfall have a major impact on the vegetation composition (Werger 1986; Fourie, De Wet & Page 1987).

Climate-influenced changes in the vegetation of the southern Kalahari are those that occur as a result of seasonal variation (short-term and mostly phenological), those affected by periodical variation in climate over a few years (medium-term), and those that result from long-term changes in climate (Werger & Leistner 1975).

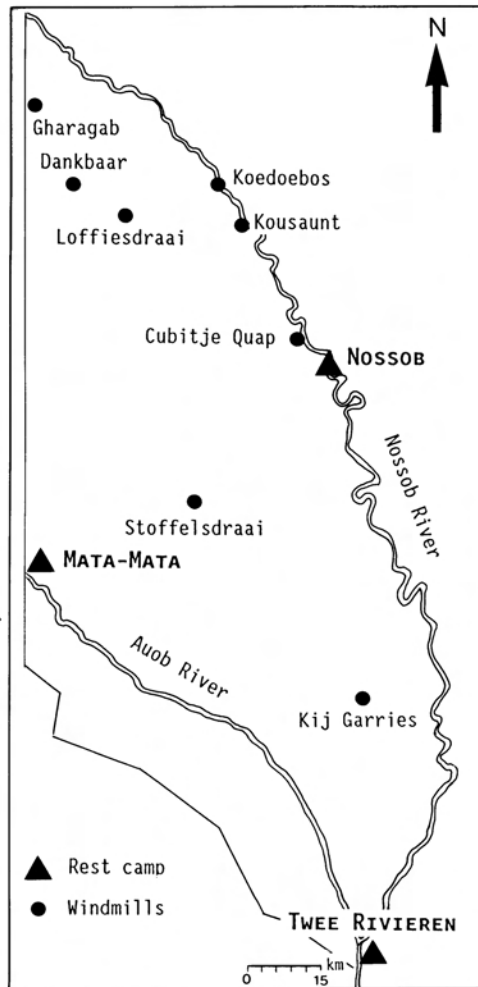


Fig. 1. Map of the Kalahari Gemsbok National Park to show the different localities of the surveys

There is a paucity of information on long-term vegetation changes in the southern Kalahari. Werger & Leistner (1975) briefly discussed the vegetation dynamics of the southern Kalahari relating it to climate and succession while Van Rooyen, Van Rensburg, Theron & Bothma (1984) gave a preliminary account of the vegetation changes over a six-year period in the Kalahari Gemsbok National Park. Fourie *et al.* (1987) recently reported on 16 years of monitoring in the southern Kalahari duneveld. Medium-term observations on variations in the vegetation cover (density) of the Kalahari were done for seven years by Choudhury & Tucker (1987) with the aid of remote satellite sensors while Skarpe & Bergstörn (1986) studied the nutrient content and digestibility of grasses over a three-year period.

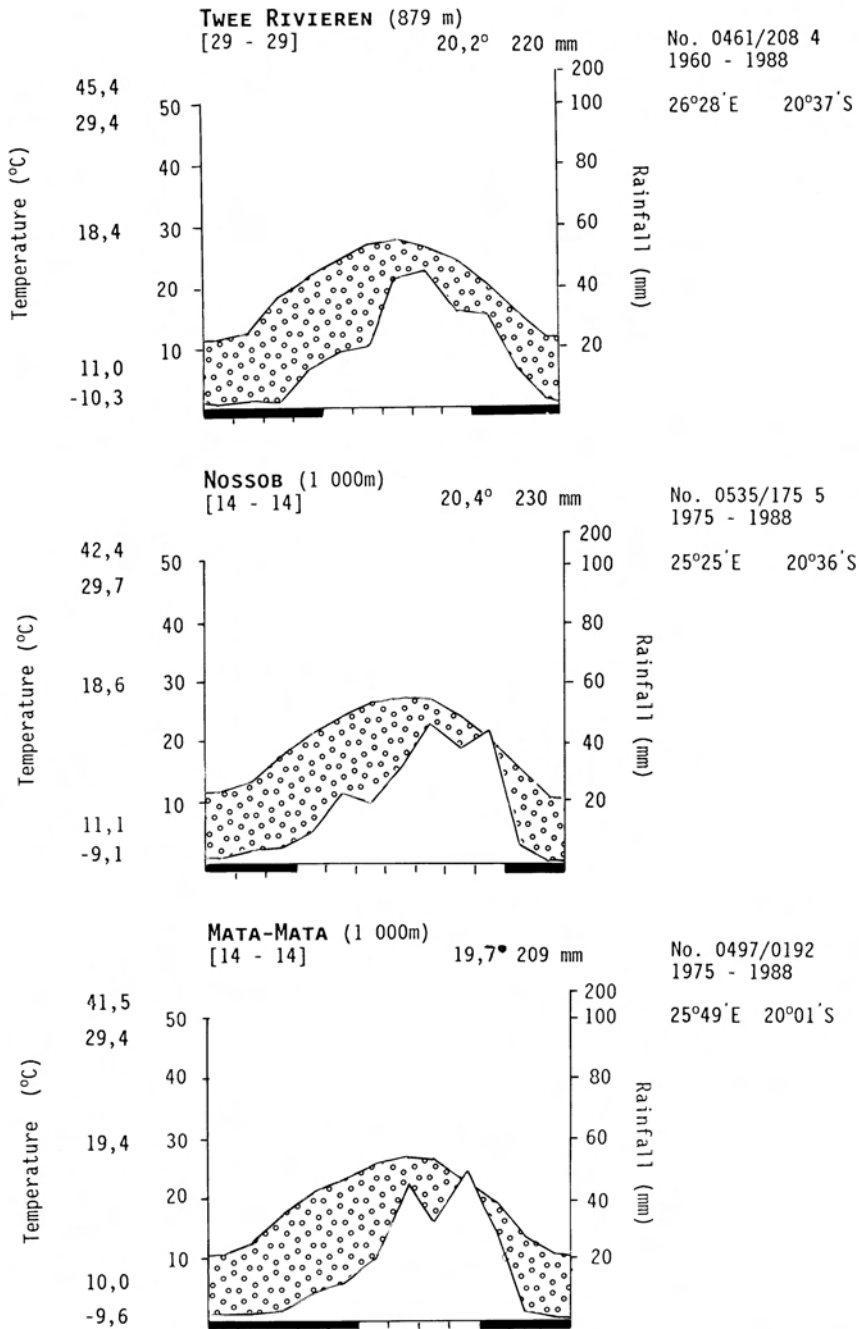


Fig. 2. Climate diagrams for Twee Rivieren, Nossob and Mata-Mata in the Kalahari Gemsbok National Park (diagrams according to Walter & Lieth (1967)).

O'Connor (1985) states that whatever conceptual models are generated to account for herbaceous dynamics of savanna grasslands, appropriate long-term data sets are required to corroborate these models. Consideration of climatic oscillations (Tyson 1986) suggests a minimum time scale of 20 years for monitoring of herbaceous vegetation, whilst consideration of the woody component suggests a time span far in excess of 20 years (O'Connor 1985). According to Hinds (1984), ecological monitoring is the purposeful and repeated examination of the state or condition of specifically defined biotic groups in relation to external stress, with emphasis on changes in the living organisms.

The present study reports on the monitoring of changes in the basal cover, presence and density of herbaceous and woody plant species from 1978 to 1989 at certain localities in the Kalahari Gemsbok National Park. The aim is also to carry on with the monitoring for at least another 10 years. The study sites are located at or near watering points (windmills) and therefore not only climate-influenced changes were measured, but also the influence of grazing, although of relatively low intensity. The first surveys were carried out before or soon after the establishment of the watering points and could therefore be used as control-surveys. Any changes in basal cover, presence, frequency and/or density that occurred since then were compared with these initial surveys. Trends regarding veld condition will be dealt with in another paper.

Localities and climate

The Kalahari Gemsbok National Park covers approximately 9 600 km² and is situated between 24°15'S and 26°30'S latitudes, and 20°00'E and 20°45'E longitudes. The height above sea level varies from 870 m at Twee Rivieren in the south to 1 080 m at Union's End in the north.

According to the habitat map of Bothma & De Graaff (1973), the different localities where the surveys were conducted (Fig. 1) are representative of the following habitats:

- dunes with trees and shrubs - Stoffelsdraai
- dunes without trees and shrubs - Kij Garries
- flat open plains along rivers - Cubitje Quap, Koedoebos and Kousaunt.

The climate of the KGNP is summarised in the climate diagrams for Twee Rivieren, Nossob and Mata-Mata (Fig. 2), which is based on data from the Weather Bureau (1986). The average annual rainfall ranges from 209 mm at Mata-Mata to 220 mm at Twee Rivieren to 230 mm at Nossob in the north. The highest rainfall occurs in the four months January to April.

The total monthly rainfall recorded from 1975 to 1989 at Nossob, as well as the dates when surveys were carried out, are indicated in Fig. 3. The years preceding the monitoring were characterised by above-average rainfall (Fig. 4), however, from 1978 to 1987 the rainfall was mostly below average. A summary of the regional climate of the southern Kalahari can be found in Werger & Coetzee (1975) and Werger (1986).

Methods

Wheel-point surveys

Monitoring the changes in basal cover and presence (frequency) of the herbaceous layer species (some woody species included), was done by means of the wheel-point method (Tidmarsh & Havenga 1955). This report covers the 11-year period from 1978 to 1989.

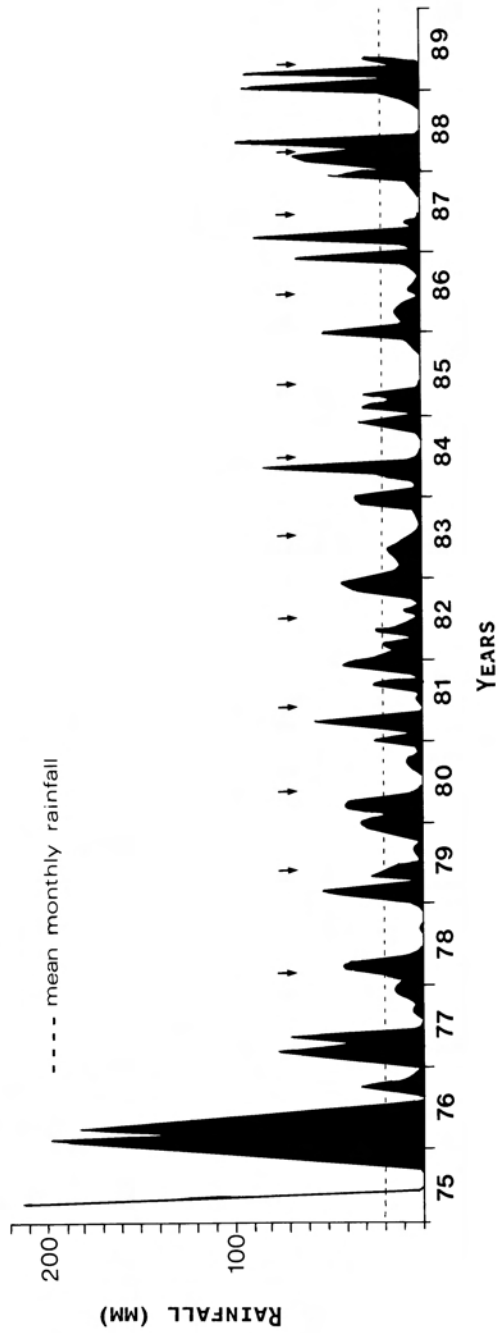


Fig.3 Monthly rainfall at Nossob Rest Camp for the period 1975 to 1989. Arrows indicate dates of surveys.

Table 1
Percentage basal cover and percentage presence of the herbaceous layer species at Kousaunt in the Kalahari Gemsbok National Park.
 *=significantly different from value of first survey

Species	% Basal cover				% Presence			
	1979	1985	1988	1989	1979	1985	1988	1989
Number of species					12	9	6	1
<i>Stipagrostis obtusa</i>	2,50	2,30	9,40*	10,60*	47,00	92,10	99,00	100,00
<i>Tragus racemosus</i>	0,30				13,80			
<i>Gisekia pharnacioides</i>					12,90	0,50		
<i>Schmidtia kalahariensis</i>	0,20				10,20		0,40	
<i>Eragrostis annulata</i>					4,20			
<i>Tribulus zeyheri</i>					3,80	3,70		
<i>Hermannia modesta</i>					2,50	0,70		
<i>Eragrostis porosa</i>					2,40			
<i>Limeum myosotis</i> var. <i>confusum</i>					2,00	0,20		
<i>Kohautia cynanchica</i>					0,70			
<i>Eragrostis truncata</i>					0,40	0,20	0,10	
<i>Cynanchum orangeanum</i>					0,10		0,10	
<i>Enneapogon desvauxii</i>						1,60	0,30	
<i>Chamaesyce inaequilatera</i>						0,90		
<i>Cucumis africanus</i>						0,10		
<i>Rhigozum trichotomum</i>			0,10				0,10	
Total	3,00	2,30	9,50*	10,60*	100,00	100,00	100,00	100,00

The different parameters calculated were:

percentage basal cover = (number of strikes/total number of wheel-points) x 100

percentage presence = (number of times a species is the nearest to the wheel-point/
total number of wheel-points) x 100

When the distance of the nearest plant was >1,5 m from the wheel-point, it was recorded as a bare area.

Transect surveys

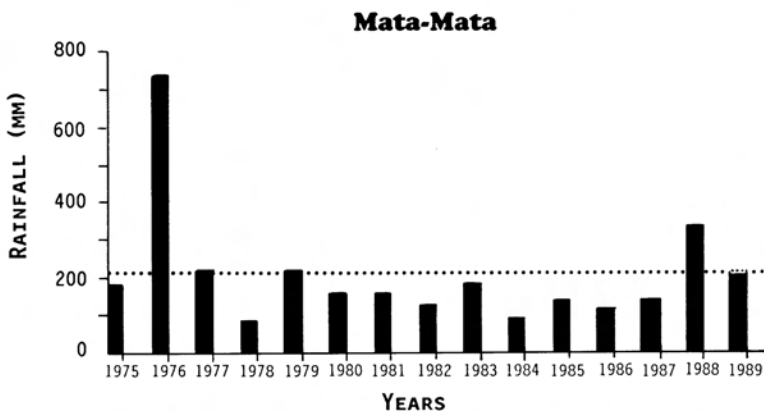
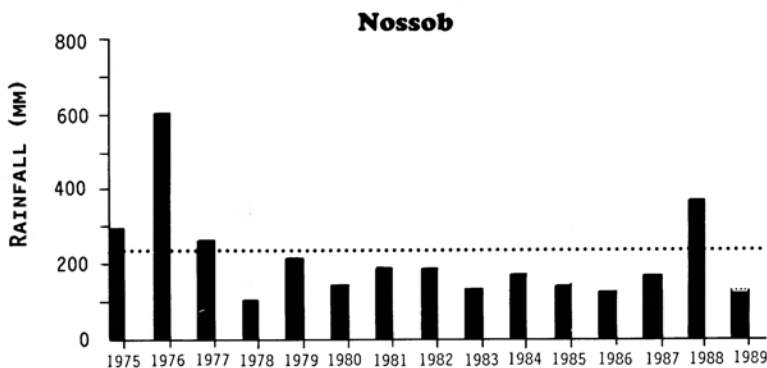
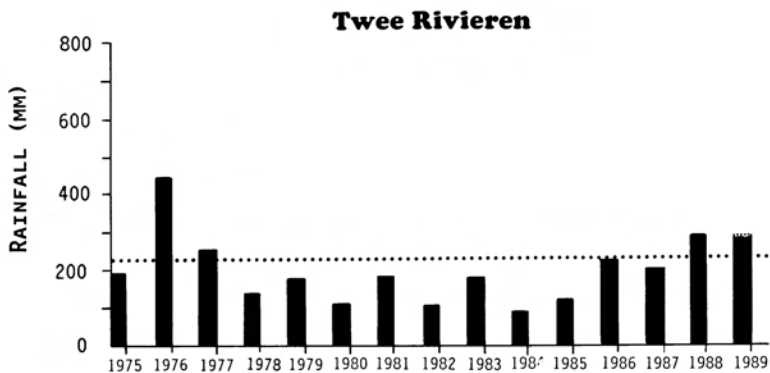
Transect surveys consisting of contiguous 2,5 m x 5 m quadrats were used for the woody species. The following values were calculated:

percentage frequency = (number of quadrats where species is present/total number of quadrats) x 100

density = number of individuals per hectare.

The surveys were conducted during the months April to June at or near artificial watering points (Fig. 1). The total number of wheel-points (1,47 m spacing between points) and number of quadrats in the transects are given below for each locality:

Kousaunt	1 000 points and 120 quadrats of 5,0 m x 2,5 m
Koedoebos	1 000 points and 120 quadrats of 5,0 m x 2,5 m
Cubitje Quap	1 000 points and 300 quadrats of 5,0 m x 2,5 m
Kij Garries	1 500 points and 300 quadrats of 5,0 m x 2,5 m
Stoffelsdraai	2 000 points and 600 quadrats of 5,0 m x 2,5 m



..... mean annual rainfall

Fig. 4. Total annual rainfall for Twee Rivieren, Nossob and Mata-Mata (data for 1989 only until April)

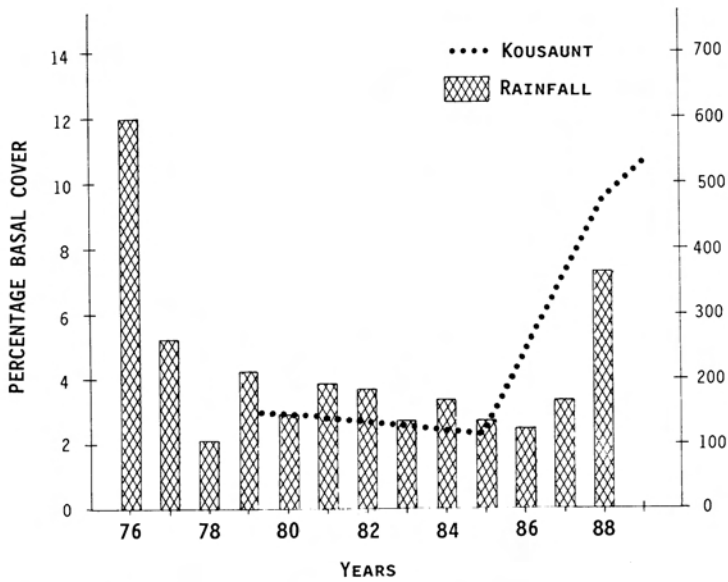


Fig. 5. Changes in percentage basal cover at Kousaunt and the rainfall for the period 1976 - 1988.

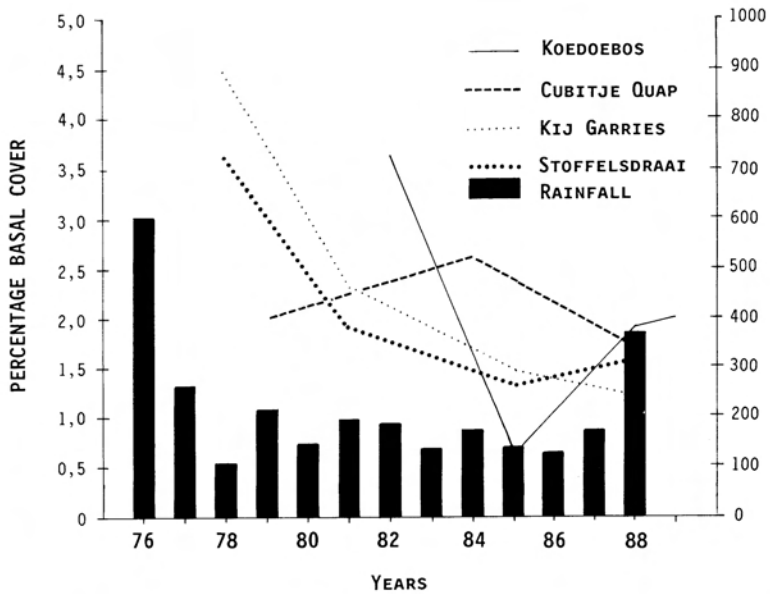


Fig. 6. Changes in percentage basal cover at different localities and rainfall for the period 1976 - 1988.

The windmills at Kousaunt and Cubitje Quap were already established windmills. At Kij Garries and Stoffeldraai the surveys were done in a contiguous line starting at the windmill. At the other localities the surveys were conducted in an area around the windmill (Koedobos) or in the immediate vicinity of the windmill (0,5 km from Cubitje Quap; 2 km from Kousaunt).

The statistical analysis was done according to Tidmarsh & Havenga. (1955). The plant species names used in the text follow Van Rooyen *et al.* (1988).

Results

The wheel-point surveys for herbaceous layer species are summarised in Tables 1, 3, 5, 7, 10, 11 and 12, and the transect surveys for woody species in Tables 2, 4, 6, 8, 9, and 13. The synchronization between the medium-term rainfall cycles or wet/dry cycles (approximately 20 years) and the period of plant surveys must be kept in mind when interpreting the results. The surveys started at the end of the wet cycle and the onset of the dry cycle (Figs. 3 and 4). The study area is probably at present entering a period of above-average rainfall again (see Tyson 1986).

Table 2
Percentage frequency and density of the woody species at Kousaunt in the Kalahari
Gemsbok National Park

Plant species	% Frequency					Density (individuals/ha)				
	1979	1983	1985	1988	1989	1979	1983	1985	1988	1989
<i>Zygophyllum tenue</i>	41,6	57,6	60,2	54,2	55,0	2982	9250	7257	4282	5149
<i>Rhigozum trichotomum</i>	22,1	9,2	15,5	19,2	25,8	474	450	451	300	934
<i>Salsola tuberculata</i>	20,8	12,0	25,2	15,8	15,0	367	490	559	380	193
<i>Plinthus karoocicus</i>	9,6	2,4	1,9		9,2	158	80	15		120
<i>Protasparagus nelsii</i>	8,8	11,2	23,3	24,2	25,8	105	350	303	354	307
<i>Plinthus sericeus</i>	2,7					30				
<i>Lycium cinereum</i>	0,8	0,4	1,0		3,3	64	100	54		80
<i>Acacia erioloba</i>	0,5					90				
<i>Eriocephalus aspalathoides</i>	0,3	3,2	5,8	9,6	2,5	2	90	85	73	20
<i>Plinthus cryptocarpus</i>	1,1		2,9	0,8	5,0	13		31	7	80
<i>Pteronia unguiculata</i>			4,9		7,5			39		220
<i>Aptosimum albomarginatum</i>				5,8	2,5				60	87
<i>Aptosimum lineare</i>					8,3					80
<i>Osteospermum muricatum</i>					1,7					33

Kousaunt

The study area is situated on an open plain along the Nossob River, about 2 km south of the windmill (Fig. 1). The total percentage basal cover decreased from 3,0 in 1979 to 2,3 in 1985 (Fig. 5), most probably as a result of the drought and with grazing as a contributing factor. The area was fairly trampled and overgrazed by the end of the wet cycle, as is also indicated by the number of annual plant species recorded. During wet seasons or years most game tend to concentrate along the river system while they disperse more into the dune areas during dry years (Mills & Retief 1984). The number of blue wildebeest remains, however, fairly constant in the river system. The significant increase in the percentage basal cover since 1985 (from 2,3 % to 10,6 % in 1989,

Fig. 5) is probably the result of high rainfall in that area during the beginning of 1988 (Fig. 3), as well as a low initial grazing pressure. A marked decrease in species diversity occurred since 1979 (Table 1) and only *Stipagrostis obtusa* was recorded in 1989. Woody species which increased in density during the dry cycle, but decreased during 1988/89 when high rainfall occurred are *Salsola tuberculata* and *Eriosephalus aspalathoides* (Table 2). *Plinthus karooicus* has, however, decreased greatly although an increase was recorded again in 1989. *Aptosimum albomarginatum*, *A. lineare* and *Osteospermum muricatum* were not recorded initially but were present especially during 1989.

Koedoebos

The survey area is situated to the north-west of Kousaunt but also on an open plain along the Nossob River (Fig. 1), directly adjacent to the dune veld. As opposed to Kousaunt, the survey at Koedoebos was done directly around the windmill and watering point (within a 200 m radius).

The total percentage basal cover decreased significantly since 1983 (Fig. 6), although the increase in percentage basal cover since 1985 was not as marked as for Kousaunt, most probably as a result of continuous grazing directly around the watering point (Table 3). The species composition did not change much over the study period, although some species disappeared and others have established since 1983. *Stipagrostis obtusa* appears to respond quickly to rainfall and showed an increase in percentage presence during 1989. Annual species such as *Eragrostis annulata*, *Hermannia modesta* and *Limeum viscosum* declined during the dry years up to 1988. These species, however, increased again after the good rains early in 1989.

Rhigozum trichotomum is the dominant woody species and maintained a relatively constant frequency and density (Table 4). Species showing a decreasing trend were *Eriosephalus aspalathoides*, *Felicia clavipilosa* and *Lycium bosciifolium*. *Blepharis mitrata*, *Protasparagus nelsii*, *Pteronia unguiculata* and *Geigeria pectidea* were more numerous in later years than in 1983.

Cubitje Quap

The survey area is situated just north of Nossob Rest Camp on a slightly sloped sandy plain along the Nossob River, about 0,5 km north of the windmill (Fig. 1).

The percentage basal cover is fairly low and did not change significantly since 1979 (Fig. 6, Table 5). The area is in general disturbed as a result of heavy grazing. There was no significant change in the number of species for each sampling year but a considerable fluctuation in species composition occurred. Species such as *Stipagrostis obtusa*, *S. ciliata*, *Eragrostis porosa*, *Rhigozum trichotomum* and *Schmidtia kalahariensis* are constantly present, but most of the other species appeared and disappeared over the period. This was probably due to rather erratic and low rainfall in that specific area. Annuals showing fluctuations between years are *Gisekia pharnacioides*, *Chamaesyce inaequilatera*, *Indigofera alternans* and *Mollugo cerviana*.

Of the woody species *Rhigozum trichotomum*, *Acacia mellifera*, *Protasparagus africanus* and *Boscia albitrunca* increased in density since 1979, whereas *Lycium cinereum* and *Grewia flava* were only recorded in recent years (Table 6). The increase in woody species in comparison to the herbaceous species may be the result of less competition from herbaceous species.

Table 3
 Percentage basal cover and percentage presence of the herbaceous stratum at
 Koedoebos in the Kalahari Gemsbok National Park * = significantly different from
 value of first survey ($P = 0,05$)

Species	% Basal cover				% Presence			
	1983	1985	1988	1989	1983	1985	1988	1989
Number of species					27	25	24	29
<i>Stipagrostis obtusa</i>	1,10	0,10*	0,90	1,10	27,60	25,70	25,30	37,20
<i>Eragrostis annulata</i>	0,80			0,20	21,90	7,20	4,00	8,30
<i>Limeum viscosum</i>	0,40				14,10	0,20	0,40	3,90
<i>Sporobolus nervosus</i>	0,20	0,30	0,40	0,10	7,60	11,20	6,10	7,80
<i>Hermannia modesta</i>	0,10				7,10	1,20	0,80	1,90
<i>Enneapogon desvauxii</i>	0,20	0,10		0,10	5,90	26,60	1,50	13,20
<i>Rhizozum trichotomum</i>	0,30	0,10	0,40	0,20	4,90	14,50	6,50	6,30
<i>Plinthus karoocicus</i>					2,60	0,10	0,10	0,50
<i>Felicia clavipilosa</i>	0,10				1,50			0,10
<i>Mollugo cerviana</i>	0,20				1,50	2,20	4,00	0,80
<i>Tribulus zeyheri</i>	0,20				0,80	3,70	0,80	2,30
<i>Hirpicium gazanioides</i>					0,70	0,50		0,10
<i>Trianthema triquetra</i>					0,60	0,70	5,70	1,70
<i>Gisekia pharnacioides</i>					0,40	0,80	0,10	0,50
<i>Indigofera alternans</i>					0,40			
<i>Dipcadi</i> sp.					0,40			
<i>Tragus racemosus</i>					0,30	0,50	0,10	0,90
<i>Erioccephalus</i> <i>aspalathoides</i>					0,30	0,40		0,50
<i>Protasparagus nelsii</i>					0,30	0,20	0,60	
<i>Geigeria pectidea</i>					0,20			0,10
<i>Lycium bosciifolium</i>					0,20	0,60	0,10	0,10
<i>Cynanchum</i> <i>orangeanum</i>					0,10	1,30	0,40	0,30
<i>Chamaesyce</i> <i>inaequilatera</i>					0,10	1,70	0,90	0,70
<i>Aptosimum</i> <i>albomarginatum</i>					0,10		0,20	0,10
<i>Citrullus lanatus</i>					0,10			0,50
<i>Cyperus margaritaceus</i>					0,10			
<i>Grewia flava</i>					0,10			
<i>Dicoma capensis</i>				0,10		0,20	6,10	4,10
<i>Schmidtia kalihariensis</i>						0,10	0,10	0,40
<i>Kohautia cynanchica</i>						0,10	4,60	0,10
<i>Helichrysum</i> <i>argyrosphaerum</i>			0,10			0,10	3,10	
<i>Solanum</i> sp.						0,10		
<i>Cucumis africanus</i>						0,10		
<i>Ifloga molluginoides</i>			0,10				23,30	2,50
<i>Stipagrostis uniplumis</i>							0,10	0,30
<i>Eragrostis porosa</i>				0,20				4,10
<i>Jatropha erythropoda</i>								0,10
Total	3,60	0,60*	1,90*	2,00*	99,90	100,00	94,90	99,40
Bare areas, no species 1,5 m from point							5,10	0,60
							100,00	100,00

Table 4
Percentage frequency and density of the woody species at Koedoebos in the Kalahari
Gemsbok National Park

Plant species	% Frequency			Density (individuals/ha)		
	1983	1985	1989	1983	1985	1989
<i>Rhigozum trichotomum</i>	78,4	86,2	77,6	5180	4155	4482
<i>Eriocephalus aspalathoides</i>	26,7	22,4	18,1	1422	940	750
<i>Plinthus karoocicus</i>	21,6	25,0	20,7	379	345	379
<i>Felicia clavipilosa</i>	12,1	6,0		776	86	
<i>Blepharis mitrata</i>	11,2	12,1	12,9	112	233	259
<i>Protasparagus africanus</i>	10,3	12,1	12,1	121	155	181
<i>Aptosimum albomarginatum</i>	6,0	5,2	7,7	233	164	130
<i>Lycium bosciifolium</i>	2,6	4,3	2,6	379	259	60
<i>Zygophyllum tenue</i>	0,9	0,9	0,9	9	9	7
<i>Pteronia unguiculata</i>		1,7	2,6		17	26
<i>Geigeria pectidea</i>		4,3	2,6		43	26

Kij Garries

The survey area is situated in the interior dune veld area on loose sandy soils (Fig. 1). The survey was conducted from the watering point, due west on a compass line for 2,25 km. The basal cover decreased significantly from 4,47 % in 1978 to 1,19 % in 1988 (Fig. 6, Table 7). The species with the biggest decrease in basal cover and presence during this period, was *Eragrostis lehmanniana*. Other species showing the same trend were *Hermannia modesta*, *Eragrostis porosa*, *E. pallens* and *Stipagrostis uniplumis*. Annual species that increased in presence during the period are *Sesamum triphyllum*, *Oxygonum dregeanum*, *Limeum viscosum*, *L. aethiopicum* and *L. fenestratum*. A relatively constant presence was maintained by *Centropodia glauca* and *Stipagrostis amabilis*, although the basal cover of *C. glauca* has declined since 1978 (Table 7). The greatest increase in number of species present occurred in the period 1978 to 1981 (19), while 16 species were not recorded again between 1981 and 1985 (Table 7).

Although it is difficult to distinguish between the influence of rainfall and grazing on the basal cover or presence of species, it is possible to draw some conclusions from Table 8. The watering point was established in 1978. Comparing the presence of species between 1978 and 1988, it is clear that *Eragrostis lehmanniana* disappeared completely in the immediate vicinity of the watering point, most probably as a result of grazing pressure. There was also a decrease in presence of *Eragrostis lehmanniana* in the sections furthest away from the watering point, which may indicate the influence of drought. The decrease in *Stipagrostis uniplumis* is also probably due to grazing pressure.

Although *Eragrostis lehmanniana* disappeared in the immediate vicinity of the watering point, there were other species that responded differently to the grazing pressure. *Indigofera alternans*, *Requienia sphaerosperma* and *Crotalaria sphaerocarpa* increased around the watering point but species such as *Sesamum triphyllum*, *Oxygonum dregeanum*, *Bulbostylis hispidula*, *Limeum viscosum* and *L. fenestratum* increased in presence over the whole length of the survey line since 1978 (Table 8).

Table 5
 Percentage basal cover and percentage presence of the herbaceous stratum at Cubitje
 Quap in the Kalahari Gemsbok National Park

Species	% Basal cover			% Presence		
	1979	1984	1988	1979	1984	1988
Number of species				15	19	18
<i>Gisekia pharnacioides</i>	0,20			30,40	0,50	
<i>Schmidtia kalihariensis</i>	0,30	0,10	0,10	29,10	1,20	9,40
<i>Stipagrostis obtusa</i>	0,90	0,30	0,40	22,40	8,10	32,80
<i>Eragrostis porosa</i>		0,10	0,30	5,30	11,00	21,80
<i>Rhigozum trichotomum</i>	0,60	0,70	0,50	4,70	2,90	11,30
<i>Limeum aethiopicum</i>				3,50	0,90	0,30
<i>Indigofera alternans</i>			0,10	1,80		11,00
<i>Stipagrostis ciliata</i>		0,10	0,10	1,60	0,40	3,30
<i>Enneapogon desvauxii</i>			0,10	0,30		3,60
<i>Cynanchum orangeanum</i>				0,20		0,20
<i>Tribulus zeyheri</i>				0,20		
<i>Trianthema triquetra</i>				0,20		
<i>Stipagrostis uniplumis</i>				0,10		
<i>Protasparagus africanus</i>				0,10	0,10	
<i>Hermannia tomentosa</i>				0,10		
<i>Chamaesyce inaequilatera</i>		0,60			40,70	2,20
<i>Mollugo cerviana</i>		0,30			11,40	0,10
<i>Indigofera daleoides</i>		0,10			8,10	
<i>Kohautia cynanchica</i>					7,20	
<i>Helichrysum argyrosphaerum</i>		0,10			3,90	1,70
<i>Lotononis furcata</i>		0,10			1,50	
<i>Grielum sinuatum</i>		0,10			0,60	
<i>Geigeria ornativa</i>					0,50	
<i>Cleome rubella</i>					0,40	
<i>Cleome kalachariensis</i>					0,40	
<i>Dimorphotheca polyptera</i>					0,10	
<i>Triraphis purpurea</i>			0,10			1,00
<i>Ifloga molluginoides</i>						0,40
<i>Monsonia</i> sp.						0,30
<i>Dicoma capensis</i>						0,30
<i>Eragrostis lehmanniana</i>						0,30
<i>Limeum viscosum</i>						0,10
Total	2,00	2,60	1,70	100,00	99,90	100,10

Table 6
Percentage frequency and density of the woody species at Cubitje Quap in the Kalahari
Gemsbok National Park

Species	% Frequency			Density (individuals/ha)		
	1979	1984	1988	1979	1984	1988
<i>Rhigozum trichotomum</i>	71,9	75,9	71,7	1205	2160	3937
<i>Acacia mellifera</i>	2,0	4,9	5,6	29	26	58
<i>Acacia erioloba</i>	0,5	1,3	1,6	5	9	13
<i>Protasparagus africanus</i>	0,5	2,0	2,0	4	11	34
<i>Hermannia tomentosa</i>	0,3			4		
<i>Aptosimum albomarginatum</i>	0,2	0,3	0,3	4	1	3
<i>Boscia albitrunca</i>	0,2	1,0	2,0	1	4	16
<i>Grewia retinervis</i>	0,2			1		
<i>Lycium cinereum</i>		0,7	3,0		4	37
<i>Grewia flava</i>		1,0	2,0		8	16
<i>Monechma genistifolium</i>		0,3	0,3		1	3
<i>Ehretia rigida</i>			0,3			3
<i>Acacia haematoxylon</i>			0,7			5
<i>Rhus tenuinervis</i>			0,3			3 3

Acacia haematoxylon shows a gradual increase in frequency and density over the study period (Table 9). *Plinthus sericeus*, *Protasparagus suaveolens* and *Boscia albitrunca* were not recorded initially but appeared later and were increasing. *Salsola tuberculata*, *Cassia italica* and *Pteronia unguiculata* have apparently disappeared from the area.

Stoffelsdraai

The survey area is also situated in the interior dune veld on loose sandy soils, except directly around the watering point where a fine textured soil occurs (Fig. 1). The survey was done along two compass lines, due west and due east, from the watering point. Each line was approximately 1,5 km long.

The basal cover decreased significantly from 3,60 % in 1978 to 1,30 % in 1985 and then increased slightly to 1,57 % in 1988 (Fig. 6, Table 10). Species such as *Hermannia modesta*, *Stipagrostis uniplumis*, *S. obtusa*, *Rhigozum trichotomum*, *Chrysocoma obtusata*, *Aristida meridionalis* and *Monechma incanum* decreased in basal cover and presence since 1978, while *Aristida stipitata*, *Helichrysum argyrosphaerum* and *Salsola tuberculata* were not recorded.

However, species such as *Schmidtia kalihariensis*, *Indigofera alternans*, *Limeum viscosum*, *Chamaesyce inaequilatera*, *Cleome kalachariensis*, *Oxygonum dregeanum* and *Requienia sphaerosperma* increased in presence since 1978.

Species that showed changes in basal cover and presence, but not specific directional trends, are *Centropodia glauca*, *Eragrostis lehmanniana*, *Aptosimum albomarginatum*, *Stipagrostis amabilis*, *S. ciliata*, and *Heliotropium ciliatum*.

According to Tables 11 and 12 the species that decreased sharply around the watering point were *Stipagrostis obtusa*, *S. uniplumis*, *Rhigozum trichotomum*, *Monechma incanum*, *Hermannia modesta* and *Chrysocoma obtusata*. The species that increased

Table 7

Percentage basal cover and percentage presence of the herbaceous stratum at Kij Garries in the Kalahari Gemsbok National Park . * = significantly different from value of first survey ($P = 0,05$)

Species	% Basal cover				% Presence			
	1978	1981	1985	1988	1978	1981	1985	1988
Number of species					22	35	31	38
<i>Eragrostis lehmanniana</i>	2,13	0,27*		0,14*	49,56	16,33	8,67	16,31
<i>Hermannia modesta</i>	0,33				13,08			
<i>Centropodia glauca</i>	1,07	1,13	0,40	0,28	8,65	12,43	10,13	7,42
<i>Stipagrostis amabilis</i>	0,47	0,20	0,53	0,49	7,50	13,25	13,87	11,02
<i>Heliotropium ciliatum</i>			0,27		6,51	5,87	46,27	2,05
<i>Eragrostis porosa</i>	0,20	0,13			3,96	6,69		
<i>Eragrostis pallens</i>	0,07		0,13		2,41	1,78	0,67	0,42
<i>Stipagrostis uniplumis</i>	0,13				2,21	2,53	2,00	0,35
<i>Aristida meridionalis</i>		0,27			1,95	6,76	0,13	0,21
<i>Indigofera alternans</i>					1,01	0,41		2,26
<i>Merremia verecunda</i>					0,80	0,14		
<i>Salsola tuberculata</i>	0,07	0,07			0,74	1,30		
<i>Rhigozum trichotomum</i>					0,40	0,14	0,67	0,35
<i>Cyperus usitatus</i>					0,27			
<i>Indigofera flavicans</i>					0,20	0,96		0,07
<i>Hermannia tomentosa</i>		0,20			0,13	9,15	3,20	2,82
<i>Aptosimum albomarginatum</i>					0,13			
<i>Chrysocoma obtusata</i>					0,13			
<i>Crotalaria spartioides</i>					0,13		0,27	
<i>Sporobolus nervosus</i>					0,13			
<i>Sericorema remotiflora</i>					0,07	0,14		0,49
<i>Schmidtia kalihariensis</i>					0,07	3,01	0,40	1,13
<i>Bulbostylis hispidula</i>				0,07		5,33		3,21
<i>Hoffmannseggia burchellii</i>						3,83		
<i>Oxygonum dregeanum</i>				0,07		1,98	1,07	4,80
<i>Cleome kalachariensis</i>						1,57	0,53	0,85
<i>Limeum aethiopicum</i>						1,16	1,33	2,81
<i>Asclepias buchenaviana</i>						0,96		
<i>Crotalaria sphaerocarpa</i>		0,07				0,68	0,40	1,55
<i>Hermibstaedtia lineare</i>			0,13			0,55	1,73	0,21
<i>Lophiocarpus tenuissimus</i>						0,61		0,49
<i>Chamaesyce inaequilatera</i>						0,41	0,53	0,35
<i>Tribulus zeyheri</i>						0,41	0,53	
<i>Sesamum triphyllum</i>				0,07		0,27	0,13	13,61
<i>Ornithogalum tenuifolium</i>						0,27	0,27	0,28
<i>Nolletia arenosa</i>						0,34		
<i>Dicoma capensis</i>						0,07		0,07
<i>Kohautia lasiocarpa</i>						0,07		
<i>Citrullus lanatus</i>						0,07		0,07
<i>Pollichia campestris</i>						0,14		

Table 7 Continued

Species	% Basal cover				% Presence			
	1978	1981	1985	1988	1978	1981	1985	1988
Number of species					22	35	31	38
<i>Filicia muricata</i>						0,14		
<i>Requienia sphaerosperma</i>							2,67	2,61
<i>Erlangea misera</i>							2,27	
<i>Gisekia pharnacioides</i>							0,53	0,35
<i>Indigofera daleoides</i>							0,40	0,21
<i>Merremia tridentata</i>							0,40	0,71
<i>Cynanchum orangeanum</i>							0,40	
<i>Cucumis africanus</i>							0,13	0,42
<i>Cassia italica</i>							0,13	
<i>Mollugo cerviana</i>							0,13	
<i>Limeum arenicolum</i>							0,13	
<i>Acacia haematoxylon</i>							0,13	
<i>Limeum viscosum</i>				0,07				17,37
<i>Limeum fenestratum</i>								3,25
<i>Grielum sinuatum</i>								0,56
<i>Dimorphotheca polyptera</i>								0,64
<i>Plexipus garipensis</i>								0,28
<i>Acrotome inflata</i>								0,07
<i>Chrysocoma ciliata</i>								0,07
<i>Phyllanthus omahekensis</i>								0,14
Other species					0,21			
Total	4,47	2,34*	1,46*	1,19*	100,04	99,96	100,12	99,88

in the immediate vicinity of the watering point were *Eragrostis lehmanniana*, *Tribulus zeyheri*, *Schmidtia kalahariensis*, *Chamaesyce inaequilatera*, *Indigofera alternans*, *Indigofera daleoides* and *Limeum viscosum*.

It seems that *Centropodia glauca* decreased near the watering point and increased further away from the watering point.

Although *Rhigozum trichotomum* showed a relatively constant frequency, there was, however, a gradual increase in density (Table 13). *Hermannia tomentosa*, *Plinthus sericeus* and *Geigeria ornativa* have apparently increased during the dry years but have decreased subsequently. Species such as *Chrysocoma obtusata*, *Salsola tuberculata* and *Pteronia unguiculata* showed a declining trend over the study period.

Discussion

The above-average rainfall during the years preceding 1978 is probably the main reason for the relatively high basal cover recorded during 1978. The basal cover at all the localities except Cubitje Quap showed a decline up to 1985 and a marginal increase again up to 1989.

Table 8
 Change in percentage presence between 1978 and 1988 of selected species of the herbaceous stratum at Kij Garies in the Kalahari Gemsbok National Park. The wheel point transects were divided into ten sections of 150 points each (section 1 at windmill)

Species	Sections																		
	1	2	3	4	5	6	7	8	9	10									
	1978	1978	1978	1978	1978	1978	1978	1978	1978	1978									
<i>Eragrostis lehmanniana</i>	69,3	67,3	2,0	64,7	9,3	50,7	8,7	31,3	19,3	39,3	28,7	42,7	34,0	48,0	24,7	53,3	18,0	46,2	16,7
<i>Hermannia modesta</i>	10,7	16,0	18,0	20,0	7,3	7,3	7,3	7,3	7,3	7,3	7,3	12,7	12,7	17,3	12,0	12,0	8,0	8,0	8,0
<i>Heliotropium ciliatum</i>	6,0	5,3	2,0	1,3	0,7	1,3	2,0	2,0	1,3	3,3	3,3	2,7	2,0	9,3	2,0	6,7	1,3	2,3	2,3
<i>Rhigozum trichotomum</i>	4,0	3,3																	
<i>Stipagrostis amabilis</i>	3,3	2,7	4,7	17,3	7,3	11,3	12,7	22,7	12,0	23,3	4,0	13,3	0,7	0,7	0,7	3,3	2,7	26,7	1,5
<i>Centropodia glauca</i>	1,3	1,3	4,7	7,3	4,0	9,3	9,3	6,0	7,3	15,3	19,3	8,7	16,7	6,0	10,0	8,0	11,3	10,7	3,0
<i>Indigofera alternans</i>	1,3	21,3																	
<i>Stipagrostis uniplumis</i>			0,7						4,7	6,7	6,7	0,7	2,7	6,0	2,7	3,3			
<i>Eragrostis pallens</i>				2,7					16,7	3,3	1,3	2,0	2,0						1,5
<i>Indigofera flavicans</i>		0,7		0,7					6,0	0,7	2,0	0,7	2,0						0,7
<i>Schmidtia kalahariensis</i>		2,0		2,0	0,7	1,3								2,0					0,7
<i>Aristida meridionalis</i>									1,3	2,7	1,3	2,0	2,0	4,7	0,7	4,0			0,8
<i>Sericorema remotiflora</i>									0,7	0,7	1,3	0,7							1,3
<i>Hermannia tomentosa</i>			5,3	3,3					3,3	0,7	4,7	4,7	4,0	4,0	0,7	0,7	0,7	1,5	1,5
<i>Limeum viscosum</i>	14,0	22,0	13,3	13,3					10,7	10,7	20,7	20,7	26,0	16,0	19,3	4,5			4,5
<i>Requienia sphaerosperma</i>	13,3	4,7	5,3									0,7							0,7
<i>Crotalaria sphaerocarpa</i>	13,3	1,3																	7,6
<i>Oxygonum dregeanum</i>	4,0	5,3	3,3	3,3					9,3	10,7	4,0	4,0		3,3	0,7				12,2
<i>Limeum fenestratum</i>	3,3	1,3	2,7	2,7					0,7	1,3	0,7	0,7	0,7	8,0	8,0				8,0
<i>Sesamum triphyllum</i>	1,3	14,0	19,3	16,7					16,7	10,7	16,7	16,7	16,7	16,0	23,3				18,2
<i>Bulbostylis hispidula</i>		2,7	4,7	2,7					2,7	3,3	3,3	3,3	3,3	6,0	6,7				1,5

Table 9
*Percentage presence and density of the woody species at Kij Garries in the Kalahari
 Gemsbok National Park*

Species	% Frequency			Density (individuals/ha)		
	1978	1985	1988	1978	1985	1988
<i>Acacia haematoxylon</i>	8,2	10,1	12,3	78	115	124
<i>Salsola tuberculata</i>	6,5			78		
<i>Rhigozum trichotomum</i>	2,9	2,3	2,3	125	99	108
<i>Chrysocoma obtusata</i>	2,3	0,7	2,9	23	10	83
<i>Aptosimum decumbens</i>	2,0	1,0		16	8	
<i>Cassia italica</i>	2,0	0,3		18	3	
<i>Grewia flava</i>	1,6	1,0	0,6	23	8	5
<i>Pteronia unguiculata</i>	1,3			13		
<i>Aptosimum albomarginatum</i>	0,7	0,3	0,6	5	3	5
<i>Rhus tenuinervis</i>	0,3	0,3		5	3	
<i>Plinthus sericeus</i>		33,5	36,8		506	699
<i>Protasparagus suaveolens</i>		1,3	1,0		10	23
<i>Boscia albitrunca</i>		0,7	0,3		5	3

The year 1978 signalled the start of a dry cycle with 1984 to 1986 the driest years recorded at Twee Rivieren, Nossob and Mata-Mata (Fig. 3). It seems likely that from 1988 a wet cycle has commenced as is reflected in the increased rainfall.

Choudhury & Tucker (1987) measured the annual average green leaf density of the Kalahari for seven consecutive years (1979-1985) by space-borne sensors on board a satellite. A pattern of consistently decreasing vegetation cover was measured over the Kalahari which is confirmed by the results of the present study.

It is clear from the present study that rainfall is an important ecological factor in the southern Kalahari. Fourie *et al.* (1987) also found that rainfall is clearly the main determinant of forage production in this environment and since it varies widely from year to year, often with alternating series of wet and dry years, forage production varies widely over time. The existence of long wet and dry rainfall periods therefore play a major role in the dynamics of the vegetation cover and species composition. The timing and amount of seasonal rainfall has a marked influence on the growth of woody species, perennial grass species and annual grass and forb species (Roux 1966; Rutherford 1980; Seely & Louw 1980; Snyman 1985).

Fourie *et al.* (1987) found that during a dry rainfall cycle *Centropodia glauca* and *Stipagrostis* spp. are the prominent species in the dune veld, although a decline in basal cover was observed for *Centropodia glauca* during the dry years of their study.

From Tables 1-14 certain trends could be observed in the species presence over the study period. Certain species maintained a relatively constant presence under the prevailing conditions, whilst others increased or decreased under the influence of rainfall and/or grazing.

Table 10
 Percentage basal cover and percentage presence of the herbaceous stratum at
 Stoffelsdraai in the Kalahari Gemsbok National Park. * = significantly different from
 value of first survey ($P = 0,05$)

Species	% Basal cover				% Presence			
	1978	1981	1985	1988	1978	1981	1985	1988
Number of species					37	44	50	54
<i>Eragrostis lehmanniana</i>	0,66	0,47	0,80	0,36	15,76	13,49	45,50	12,38
<i>Hermannia modesta</i>	0,05		0,05		13,77	1,64	0,10	0,21
<i>Centropodia glauca</i>	1,37	0,34		0,56	10,56	7,41	4,70	7,89
<i>Stipagrostis uniplumis</i>	0,05	0,09			8,49	2,72	3,15	1,39
<i>Rhizozum trichotomum</i>	0,20	0,09		0,05	8,44	2,63	2,80	0,98
<i>Chrysocoma obtusata</i>					8,44	0,22	0,30	0,05
<i>Aristida meridionalis</i>	0,25	0,22	0,05		7,52	8,45	2,70	0,05
<i>Monechma incanum</i>	0,36	0,13	0,05	0,10	5,49	2,24	2,60	1,81
<i>Aptosimum</i>								
<i>albomarginatum</i>	0,15		0,05		3,41	1,55	2,15	1,70
<i>Stipagrostis obtusa</i>	0,36	0,04	0,05	0,15	3,25	1,25	1,70	1,03
<i>Stipagrostis amabilis</i>	0,05	0,09		0,05	3,25	3,07	0,90	2,68
<i>Stipagrostis ciliata</i>	0,05	0,13		0,10	2,54	0,82	1,25	1,29
<i>Aristida stipitata</i>	0,05				2,14	0,78	0,35	
<i>Helichrysum</i>								
<i>argyrosphaerum</i>					1,32	0,04	1,20	
<i>Salsola tuberculata</i>		0,04			1,12	0,22		
<i>Schmidtia kalihariensis</i>		0,13	0,20		0,56	23,75	12,10	7,74
<i>Indigofera daleoides</i>				0,05	0,56	0,43	0,15	2,53
<i>Indigofera flavicans</i>					0,50	0,82	0,15	0,98
<i>Heliotropium ciliatum</i>		0,04			0,46	4,48	3,15	4,18
<i>Hermannia tomentosa</i>					0,46	1,00	1,45	0,77
<i>Sericorema remotiflora</i>					0,46	0,69	0,20	0,26
<i>Salsola rabieana</i>					0,29			
<i>Cucumis africanus</i>					0,25			
<i>Hoffmannseggia burchellii</i>					0,16			
<i>Blepharis mitrata</i>					0,15	0,13		
<i>Harpagophytum procumbens</i>					0,15	0,13	0,15	
<i>Salsola kali</i>					0,10	0,04		
<i>Protasparagus africanus</i>					0,10			
<i>Aizoon schellenbergii</i>					0,10			
<i>Indigofera alternans</i>					0,10	1,64	1,45	5,11
<i>Acacia haematoxylon</i>					0,10			
<i>Aristida</i> sp.					0,05			
<i>Elephantorrhiza elephantina</i>					0,05			0,05
<i>Rhus tenuinervis</i>					0,05			
<i>Boscia albitrunca</i>					0,05			
<i>Limeum viscosum</i>					0,05	0,43	0,25	11,55
<i>Tribulus zeyheri</i>					0,05	1,34	0,60	1,75
<i>Eragrostis porosa</i>		0,09				10,30	1,45	
<i>Lotononis furcata</i>						1,51		0,31
<i>Mollugo cerviana</i>						1,25	0,80	

Table 10 continued

Species	% Basal cover				% Presence			
	1978	1981	1985	1988	1978	1981	1985	1988
Number of species					37	44	50	54
<i>Bulbostylis hispidula</i>						0,82	0,05	0,67
<i>Gisekia pharnacioides</i>						0,69	0,65	
<i>Chamaesyce inaequilatera</i>			0,05	0,10		0,65	3,00	13,30
<i>Citrullus lanatus</i>						0,65		0,52
<i>Geigeria ornativa</i>						0,56		0,15
<i>Cleome kalachariensis</i>				0,05		0,34	0,20	2,01
<i>Aptosimum lineare</i>						0,22		0,72
<i>Eragrostis annulata</i>						0,22		
<i>Sesamum triphyllum</i>						0,13	0,05	0,83
<i>Limeum fenestratum</i>						0,09		1,19
<i>Pollichia campestris</i>						0,09	0,30	0,21
<i>Hermestaedtia lineare</i>						0,09		
<i>Crotalaria sphaerocarpa</i>						0,04	0,20	0,41
<i>Aptosimum decumbens</i>						0,04	0,10	1,24
<i>Triraphis purpurea</i>							0,80	0,52
<i>Acanthosicyos naudinianus</i>							0,65	0,26
<i>Requienia sphaerosperma</i>							0,40	2,48
<i>Oxygonum dregeanum</i>							0,25	3,30
<i>Androcymbium</i> sp.							0,25	0,88
<i>Plinthus sericeus</i>							0,25	
<i>Crotalaria spartioides</i>							0,20	
<i>Limeum arenicolum</i>							0,20	
<i>Dicerocaryum eriocarpum</i>							0,20	
<i>Acrotome inflata</i>							0,10	0,41
<i>Talinum cafferum</i>							0,10	
<i>Kohautia lasiocarpa</i>							0,05	
<i>Merremia tridentata</i>							0,05	0,10
<i>Clutia natalensis</i>							0,05	
<i>Peliostomum leucorrhizum</i>							0,05	
<i>Merremia verecunda</i>							0,05	
<i>Limeum aethiopicum</i>								2,48
<i>Plexipus garipensis</i>								0,15
<i>Dimorphotheca polyptera</i>								0,10
<i>Cynanchum orangeanum</i>								0,10
<i>Ifloga molluginoides</i>								0,10
<i>Grielum sinuatum</i>								0,05
<i>Dicoma schinzii</i>								0,05
<i>Geigeria filifolia</i>								0,05
<i>Enneapogon desvauzii</i>								0,05
<i>Hermannia bicolor</i>								0,05
<i>Pancreatium tenuifolium</i>								0,05
<i>Dicoma capensis</i>								0,05
<i>Indigofera charlieriana</i>								0,05
Other species					0,10	2,00	0,40	
Bare areas								0,67
Total	3,60	1,90*	1,30*	1,57*	100,40	101,10	99,90	99,89

Table 11

Changes in percentage presence between 1978 and 1988 of selected species of the herbaceous stratum at Stoffelsdraai (East) in the Kalahari Gemsbok National Park. The wheel point transects were divided into seven sections of 150 points each (section 1 at windmill)

Species	Sections													
	1 1978	1988	2 1978	1988	3 1978	1988	4 1978	1988	5 1978	1988	6 1978	1988	7 1978	1988
<i>Rhigozum trichotomum</i>	40,0	14,7	10,7	0,7										
<i>Monechma incanum</i>	30,7	2,0	4,0	2,7										
<i>Stipagrostis obtusa</i>	5,3	1,3	14,7	9,3										
<i>Stipagrostis ciliata</i>	5,3	2,7	1,3		4,0	2,0	4,0		2,7	3,3	1,3		4,4	
<i>Hermannia modesta</i>	5,3		24,0		17,3				3,3					
<i>Aptosisum alborarginatum</i>	2,7	1,3		3,3										
<i>Schmidtia kalahariensis</i>	1,3	6,0	6,7	16,0			8,7		2,7	4,7		2,0		7,0
<i>Chrysocoma obtusata</i>	1,3	0,7	8,0		4,0									
<i>Eragrostis lehmanniana</i>		5,3	13,3	10,7	41,3	18,0	81,3		10,7	8,7	30,7	6,6	23,0	9,0
<i>Stipagrostis uniplumis</i>		0,7	5,3		13,3				0,7	0,7	14,7	7,3	13,3	3,0
<i>Centropodia glauca</i>		0,7	2,7	1,3	1,3	2,0	9,3		8,0	17,3	20,6	36,0	26,5	34,0
<i>Tribulus zeyheri</i>		5,3	1,3	1,3					2,7	3,3	4,0	0,7	14,2	11,0
<i>Stipagrostis amabilis</i>					5,3	2,7	2,7		2,0	6,0	4,0	10,7	14,2	
<i>Aristida meridionalis</i>					1,3				0,7	24,0	21,3			
<i>Heliotropium ciliatum</i>				7,3	1,3	7,3			1,3	0,7	0,7	6,0		8,0
<i>Indigofera flavicans</i>					1,3	0,7	6,7		2,0	2,0	0,7	1,3		1,0
<i>Sericorema remoitiflora</i>				0,7	1,3							0,7		
<i>Limeum viscosum</i>		13,3		11,3		8,0			31,3	0,7	31,3	13,3		11,0
<i>Indigofera daleoides</i>		13,3		4,0					2,0					
<i>Chamaesyce inaequilatera</i>		8,0		3,3		23,3				1,3		2,7		
<i>Indigofera alternans</i>		3,3		4,7		0,7								
<i>Oxygonum dregeanum</i>		1,3		0,7		10,7			9,3	12,7				
<i>Aptosisum decumbens</i>		0,7		0,7		1,3			0,7					
<i>Requienia sphaerosperma</i>		0,7		3,3		4,7			4,7	8,0		6,0		1,0
<i>Limeum aethiopicum</i>				3,3		1,3			6,7					
<i>Cleome kalahariensis</i>				2,7		2,0			4,7					
<i>Limeum fenestratum</i>				1,3		0,7			2,0	3,3				5,0
<i>Hermannia tomentosa</i>				0,7		1,3								2,0

Table 12
 Changes in percentage presence between 1978 and 1988 of selected species of the herbaceous stratum at Stoffelsdraai (West) in the
 Kalahari Gemsbok National Park. The wheel point transects were divided into seven sections of 150 points each (section 1 at windmill)

Species	Sections						
	1	2	3	4	5	6	7
	1978	1978	1978	1978	1978	1978	1978
<i>Stipagrostis uniplumis</i>	22,7	2,7	20,0	1,3	4,7	4,0	2,7
<i>Rhigozum trichotomum</i>	16,7	23,3	20,7	1,3	18,6	0,7	
<i>Aptosimum albonarinatum</i>	13,3	2,7	10,7	1,3	3,3	0,7	12,8
<i>Monechma incanum</i>	11,3	4,7	25,3	6,0	0,7		
<i>Chrysocoma obtusata</i>	8,7	12,0	2,0		30,7	1,3	18,7
<i>Stipagrostis obtusa</i>	7,3	13,3	4,7	2,6	3,3	1,3	
<i>Hermannia modesta</i>	4,0	3,3	10,0	8,7	18,0	0,7	0,7
<i>Aristida meridionalis</i>	3,3		0,7	10,0	2,0	1,3	44,0
<i>Centropodia glauca</i>	2,7	1,3	0,7	13,3	4,6	3,3	1,3
<i>Stipagrostis amabilis</i>	1,3	0,7				8,0	4,6
<i>Eragrostis lehmanniana</i>	0,7	6,0	0,7	22,6	1,3	2,0	8,0
<i>Sericorema remotiflora</i>	0,7	2,7	2,7		9,3	4,0	4,0
<i>Helictotriopium ciliatum</i>	0,7	1,3			0,7	1,3	8,7
<i>Stipagrostis ciliata</i>	0,7	2,0	2,7	6,7	1,3	0,7	2,0
<i>Indigofera alternans</i>	2,7	2,0	0,7	0,7	0,7	6,7	1,3
<i>Hermannia tomentosa</i>	13,3		24,0	0,7	4,7	4,7	6,0
<i>Indigofera flavicans</i>	1,3				0,7	0,7	0,7
<i>Chamaesyce inaequilatera</i>	16,0		16,0	1,3	0,7	1,3	3,3
<i>Limeum viscosum</i>	14,7			28,7	0,7	0,7	0,7
<i>Tribulus zeyheri</i>	6,7			1,3	24,0	19,3	24,0
<i>Indigofera daleoides</i>	5,3			1,3		16,0	16,0
<i>Requienia sphaerosperma</i>	4,7			2,7			2,7
<i>Schmidtia kalahariensis</i>	3,3			6,0	2,7	6,7	2,7
<i>Cleome kalahariensis</i>	0,7			9,3	9,3	18,0	7,3
<i>Oxygonum dregeanum</i>	0,7			1,3		10,7	6,0
<i>Limeum aethiopicum</i>	0,7			0,7		2,7	0,7
<i>Limeum fenestratum</i>	0,7			3,3	2,0	0,7	2,6
<i>Aptosimum decumbens</i>	0,7			1,3	2,0	4,0	5,3

Table 13
 Percentage frequency and density of the woody species at Stoffelsdraai in the Kalahari
 Gemsbok National Park

Species	% Basal cover				Density (individuals/ha)			
	1978	1981	1985	1988	1978	1981	1985	1988
<i>Rhigozum trichotomum</i>	27,9	23,7	27,9	27,4	879	901	964	1262
<i>Chrysocoma obtusata</i>	26,4	10,2			631	199		
<i>Monechma incanum</i>	21,8	24,5	23,8	29,4	436	1398	759	1367
<i>Aptosimum</i>								
<i>albomarginatum</i>	21,6	16,9	24,5	22,6	889	1686	1150	1539
<i>Hermannia tomentosa</i>	6,7	25,7	16,6	1,0	79	611	254	8
<i>Acacia haematoxylon</i>	5,8	9,4	10,2	9,5	52	89	89	78
<i>Aptosimum decumbens</i>	4,7	6,5			140	106		
<i>Salsola</i> sp.	3,1	6,4			30	64		
<i>Pteronia unguiculata</i>	2,0			0,7	37			5
<i>Protasparagus africanus</i>	1,7	2,1	0,9	0,5	10	16	9	9
<i>Acacia mellifera</i>	1,3	1,1	0,2	1,3	12	9	1	11
<i>Grewia flava</i>	1,2	1,9	1,6	2,5	10	28	13	29
<i>Boscia albitrunca</i>	0,9	0,7	0,3	0,7	7	5	4	7
<i>Lycium bosciifolium</i>	0,2	1,1	0,5	0,7	1	9	11	8
<i>Rhus tenuinervis</i>	0,2	1,3	0,3	0,5	1	23	4	4
<i>Ehretia rigida</i>	0,2	0,5		0,5	1	14		7
<i>Plinthus sericeus</i>		3,2	5,0	1,3		31	44	16
<i>Geigeria ornativa</i>		3,0	3,8	0,2		25	66	1
<i>Acacia erioloba</i>		1,2		1,8		9		16
<i>Elephantorrhiza</i>								
<i>elephantina</i>		0,3		0,5		15		19
<i>Grewia retinervis</i>				0,2				1

Species maintaining a relatively constant presence were *Aptosimum albomarginatum*, *Eriocephalus aspalathoides*, *Heliotropium ciliatum*, *Hermannia tomentosa*, *Rhigozum trichotomum*, *Stipagrostis amabilis*, *S. ciliata* and *Sporobolus nervosus*.

Stipagrostis obtusa and to a lesser extent *S. uniplumis* showed greater fluctuation due to changes in climate and/or grazing pressure. According to Fourie *et al.* (1987) and results from the present study, *Centropodia glauca* only declines during extremely wet or dry years. It, however, increases in moderately dry years. *Rhigozum trichotomum* is generally regarded as an encroacher species under conditions of overgrazing (Moore, Van Eck, Van Niekerk & Robertson 1988). No evidence of an increase in *Rhigozum trichotomum* was found by Fourie *et al.* (1987) over a 16-year period, and no clear trend could be found during the present study.

Species that decreased due to low rainfall are the following:

Aristida meridionalis
Eragrostis annulata

Hermannia modesta
Hermannia tomentosa

Eragrostis porosa
Felicia clavipilosa
Schmidtia kalihariensis

Hoffmannseggia burchellii
Limeum aethiopicum

Fourie *et al.* (1987) also found that *Aristida meridionalis* and *Eragrostis lehmanniana* decreased during the dry years and increased during wet years. Species increasing due to rainfall under relatively undisturbed conditions are *Stipagrostis obtusa*, *S. uniplumis*, *Enneapogon desvauxii* and *Eragrostis annulata*.

Species decreasing probably as a result of overgrazing are:

<i>Eragrostis lehmanniana</i>	<i>Monechma incanum</i>
<i>Hermannia modesta</i>	<i>Plinthus karooicus</i>
<i>Hirpicium gazanioides</i>	<i>Stipagrostis uniplumis</i>

Species increasing in higher rainfall years as a result of trampling and grazing appear to be:

<i>Chamaesyce inaequilatera</i>	<i>Limeum fenestratum</i>
<i>Dicoma capensis</i>	<i>Limeum viscosum</i>
<i>Eragrostis porosa</i>	<i>Mollugo cerviana</i>
<i>Gisekia pharnacioides</i>	<i>Oxygonum dregeanum</i>
<i>Ifloga molluginoides</i>	<i>Plexipus garipensis</i>
<i>Indigofera alternans</i>	<i>Sesamum triphyllum</i>
<i>Kohautia cynanchica</i>	<i>Tribulus zeyheri</i>
<i>Limeum aethiopicum</i>	<i>Triraphis purpurea</i>
<i>Schmidtia kalihariensis</i>	

An increase in *Schmidtia kalihariensis* is presumed to be caused by overgrazing or other disturbance (Werger & Leistner 1975; Werger & Coetzee 1977). However, Skarpe (1986) did not find it particularly often around villages and cattle posts in western Botswana and observations during this study suggest that it appears in large numbers in disturbed areas only following high rainfall.

Species that seem to increase as a result of trampling and grazing only i.e. independent of rainfall, are:

<i>Cleome kalachariensis</i>	<i>Heliotropium ciliatum</i>
<i>Crotalaria sphaerocarpa</i>	<i>Requienia sphaerosperma</i>
<i>Enneapogon desvauxii</i>	<i>Schmidtia kalihariensis</i>
<i>Helichrysum argyrosphaerum</i>	<i>Tragus racemosus</i>

Concluding remarks

Although some conclusions could be drawn from these surveys, there is a need for further research. It is almost impossible to distinguish between the causal factors e.g. rainfall and grazing, involved in the sometimes significant changes that occurred in the herbaceous stratum over the study period. Exclusion plots were not used to determine the changes in vegetation in the absence of large herbivore grazing.

It does seem that short-term rainfall events have a marked influence on the presence or dominance of annual species. Depending on the timing of these events within the year, summer annuals or winter annuals could be favoured (Leistner 1967).

Perennial grasses, dwarf shrubs and juvenile shrubs and trees react more to the medium-term wet/dry climate cycles than to short-term events. A general decline in the cover of the herbaceous stratum was, for example, recorded during the past decade, when mostly below-average rainfall occurred. The species diversity generally increased over the years which could be attributed to an increase in forb species.

Acknowledgements

The surveys involved in this monitoring project were done with the assistance of the Honours students in Wildlife Management and in Botany of the University of Pretoria over many years. Financial support and equipment were provided by the University of Pretoria. We are grateful to the National Parks Board for the opportunity to carry out this project. We also thank Mr. and Mrs. E.A.N. le Riche for their assistance, support and hospitality as well as Dr. G. de Graaff for his contributions over the years.

References

- BOTHMA, J. DU P. and G. DE GRAAFF. 1973. A habitat map of the Kalahari Gemsbok National Park. *Koedoe* 16: 181-188.
- CHOUDHURY, B.J. and C.J. TUCKER. 1987. Satellite observed seasonal and inter-annual variation of vegetation over the Kalahari, The Great Victoria Desert, and The Great Sandy Desert: 1979-1984. *Remote Sensing of Environment* 23: 233-241.
- FOURIE, J.H., N.J. DE WET, and J.J. PAGE. 1987. Veld condition and trend in Kalahari duneveld under an extensive stock production system. *Journal of the Grassland Society of Southern Africa* 4: 48-54.
- HINDS, W.T. 1984. Towards monitoring of long-term trends in terrestrial ecosystems. *Environmental Conservation* 11: 11-18.
- LEISTNER, O.A. 1967. The plant ecology of the southern Kalahari. *Memoirs of the Botanical Survey of South Africa* 38: 1-172.
- LEISTNER, O.A. and M.J.A. WERGER. 1973. Southern Kalahari phytosociology. *Vegetatio* 28: 353-399.
- MILLS, M.G.L. and P.F. RETIEF. 1984. The response of ungulates to rainfall along the riverbeds of the southern Kalahari. *Koedoe* 27: 129-141.
- MOORE, A., J.A.J. VAN ECK, J.P. VAN NIEKERK and B.L. ROBERTSON. 1988. Evapotranspirasie in drie plantgemeenskappe van 'n *Rhigozum trichotomum* habitat te Upington. *Journal of the Grassland Society of Southern Africa* 5: 80-84.
- NOY-MEIR, I. 1973. Desert ecosystems: Environment and producers. *Annual Review of Ecology and Systematics* 4: 25-51.
- O'CONNOR, T.G. 1985. A synthesis of field experiments concerning the grass layer in the savanna regions of southern Africa. *South African National Programmes Report No. 114.*, F.R.D., CSIR.
- ROUX, P.W. 1966. Die uitwerking van seisoensreënval en beweiding op gemengde Karooveld. *Proceedings of the Grassland Society of Southern Africa* 1: 103-110.
- RUTHERFORD, M.C. 1980. Annual plant production-precipitation relations in arid and semi-arid regions. *South African Journal of Science* 76: 53-56.
- SEELY, M.K. and G.N. LOUW. 1980. First approximation of the effects of rainfall on the ecology and energetics of a Namib desert dune ecosystem. *Journal of Arid Environments*: 3: 25-54.
- SKARPE, C. 1986. Plant community structure in relation to grazing and environmental changes along a north-south transect in the western Kalahari. *Vegetatio* 68: 3-18.
- SKARPE, C. and R. BERGSTRÖM. 1986. Nutrient content and digestibility of forage plants in relation to plant phenology and rainfall in the Kalahari, Botswana. *Journal of Arid Environments* 11: 147-164.

- SNYMAN, H.A. 1985. Reënval as beperkende omgewingsfaktor wat plantsamestelling en produksie beïnvloed. *Glen Agric* 14: 21-24.
- TIDMARSH, C.E.M. and C.M. HAVENGA. 1955. The wheel point method of survey and measurement of semi-open grasslands and Karoo vegetation in South Africa. *Memoirs of the Botanical Survey of South Africa* 29: 1-49.
- TYSON, P.D. 1986. *Climatic Change and Variability in Southern Africa*. Oxford: Cape Town.
- VAN ROOYEN, N., D.J. VAN RENSBURG, G.K. THERON and J. DU P. BOTHMA. 1984. A preliminary report on the dynamics of the vegetation of the Kalahari Gemsbok National Park. *Koedoe* 27 (Suppl.): 143-152.
- VAN ROOYEN, N., D.J. VAN RENSBURG, G.K. THERON and J. DU P. BOTHMA. 1988. A check list of flowering plants of the Kalahari Gemsbok National Park. *Koedoe* 31: 115-135.
- WALTHER, H and H. LIETH. 1960. *Klimadiagramm - Weltatlas*. Jena: Fischer.
- WEATHER BUREAU. 1986. *Climate of South Africa*. Climate statistics up to 1984. WB 40. Pretoria: Government Printer.
- WERGER, M.J.A. 1978. Vegetation structure of the southern Kalahari. *Journal of Ecology* 66: 933-941.
- WERGER, M.J.A. 1986. The Karoo and southern Kalahari. Pp. 283-359. In: EVENARI, M., I. NOY-MEIR and D.W. GOODALL (eds.). *Hot deserts and Arid Shrublands*. Amsterdam: Elsevier.
- WERGER, M.J.A. and B.J. COETZEE. 1975. A west-east vegetation transect through Africa south of the Tropic of Capricorn. *Bothalia* 11: 539-560.
- WERGER, M.J.A. and B.J. COETZEE. 1977. A phytosociological and phytogeographical study of Augrabies Falls National Park, Republic of South Africa. *Koedoe* 20: 11-51.
- WERGER, M.J.A. and O.A. LEISTNER. 1975. Vegetationsdynamik in der südlichen Kalahari. Pp. 135-158. In: SCHMIDT, W. (ed.). *Sukzessionsforschung*. Berichte über das Internationale Symposium der Internationalen Vereinigung für Vegetationskunde, Rinteln 1973. Cramer: Vaduz.