VEGETATION CHANGES AT THE BOESMANSKOP RESEARCH TRIALS, GROOTFONTEIN, 2007-2015

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INTRODUCTION

The Boesmanskop research trials are located on the farm of the Grootfontein Agricultural Development Institute near Middelburg in the Eastern Karoo. The area falls within the Karoo biome, and the vegetation has been described as False Upper Karoo (Acocks, 1988), Eastern Mixed Nama Karoo (Low & Rebelo, 1996), and most recently as Eastern Upper Karoo (Mucina & Rutherford, 2006). The Boesmanskop trials were established in 1989 to monitor the effect of recommended grazing systems using animals stocked at recommended rates on vegetation change over time (Du Toit, 2004).

The trials comprise an area of land approximately 206 ha in extent which is divided into eleven paddocks (Figure 1). Eight of these are approximately 14 ha each and lie on the plains or pediments, and three paddocks are approximately 30 ha each and are situated on a low-lying hill. Aerial imagery indicates that the vegetation across the trials is not uniform, possibly owing to differences in slope, soils, or geology (Figure 2). The trials are stocked with a single group of animals (six cattle and 36 sheep) that graze the smaller plains paddocks for two weeks and the larger hill paddocks for four weeks each on an ongoing rotation. The long-term stocking rate is approximately 16 hectares per animal unit, and the ratio of sheep:cattle is approximately 1:1 on a metabolic mass basis (Meissner, 1982).

The Boesmanskop trials do not constitute an experiment as there is only one treatment. Rather, they provide an opportunity to observe compositional changes over time on two contrasting land types (hills and plains). Animal weights and on-site rainfall are recorded. In 2015 an eddy covariance tower was erected on the site and records a range of environmental parameters including carbon fluxes across the immediate landscape.

Two unplanned fires occurred in the trials (not on the same place) in 1976 and in 2012. Details of the short-term response of the vegetation to the 2012 fire are described by du Toit et al. (2014).

The purpose of this paper is to provide an overview of vegetation changes that have taken place on the Boesmanskop trials since 2015 on a species and growth-form basis and interpret these results within the context of land type (plains or hills) and rainfall.

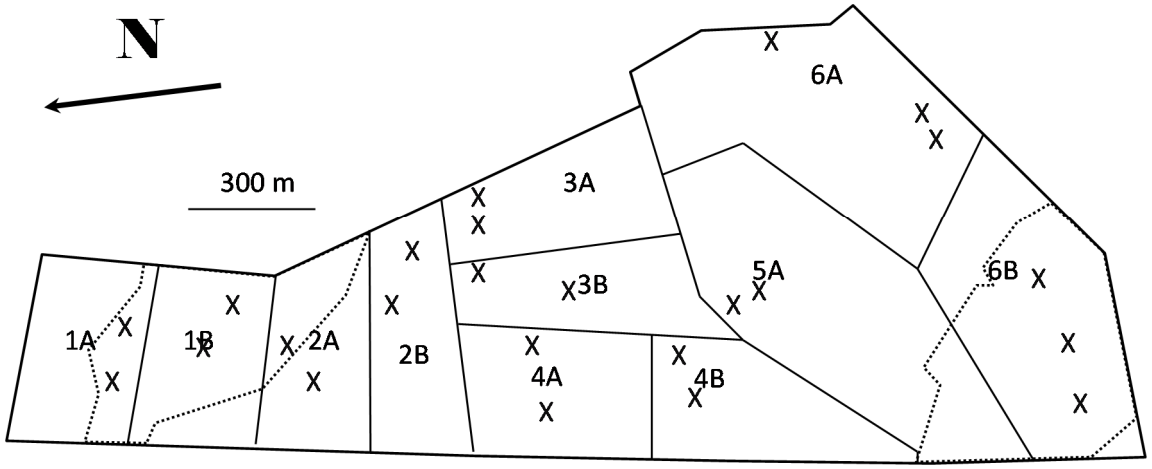

Figure 1. Layout of the Boesmanskop trials at Grootfontein. Dotted lines demarcate the approximate position of fires in 1976 (left) and 2012 (right). 'X' marks show the southern end of each 100 m transect (except for 5A, where they show the western end)

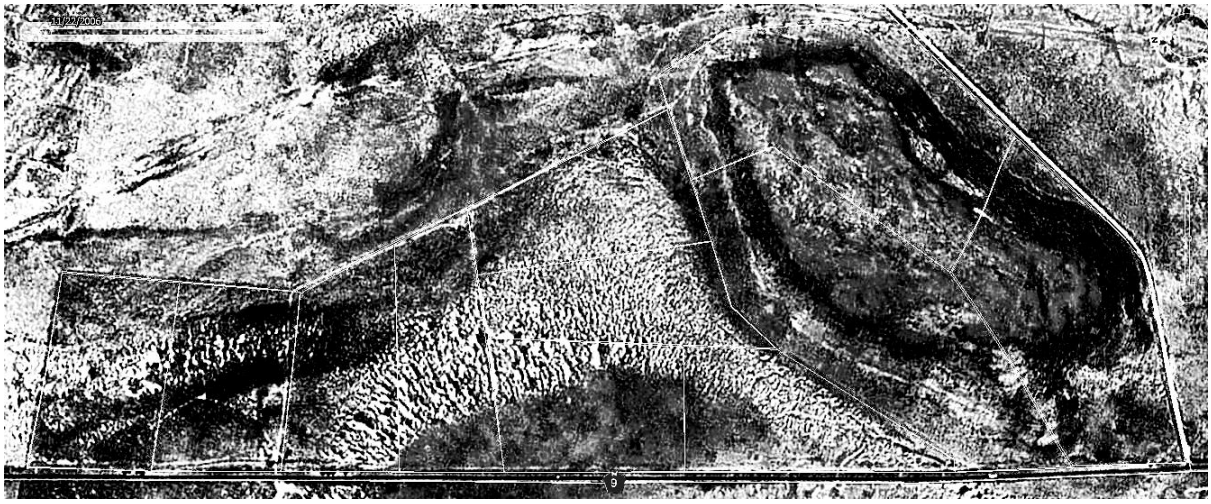

Figure 2. Google Earth Image (converted to black and white and enhanced) of the Boesmanskop trials showing apparent variation in vegetation, geology and/or soils

METHODS

Plant composition was recorded annually from 2007 to 2015 in autumn by recording the plant species at each meter along two or three pairs (for paddocks 6A and 6B) of 100 m transects approximately 15 m apart. If no plant was encountered, 'bare ground' was recorded. The start of each transect was demarcated by permanent metal poles, and the transects extended 100 m (measured using a tape measure) in a northerly direction (easterly for paddock 5A). Because the ends of the transects were not demarcated, the actual position of each transect varied slightly over time.

Data were relativized to 100% and Bare Ground treated as a pseudo-species. Species were classified according to longevity and growth form (Appendix 1). Species composition was described using

Non-Metric Multidimensional Scaling (NMMS). Directional trends in abundance of dominant growth forms and of species were determined using linear regression.

RESULTS

Rainfall

Rainfall over the period followed the typical seasonal pattern where most rain fell during the summer. Rainfall from 2007-2015 was on average 502 mm per annum, notably higher than the long-term average of 372 mm. From 2009-2012 rainfall was much higher than the average (624 mm), and from 2013-2015 was close to average (370 mm).

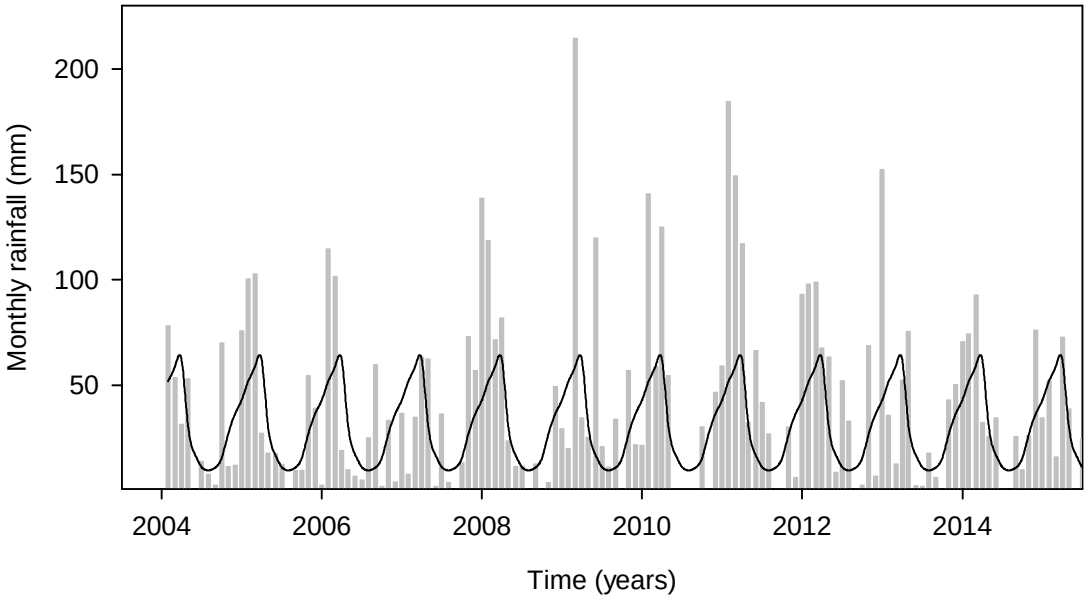

Figure 3. Actual (bars) and average (line) monthly rainfall at Grootfontein from 2004 to 2015

Multivariate analysis of species composition

The ordination indicated that variation in species composition is smaller over time (Figure 4) than over space (Figure 5). However, there are signs that the total dissimilarity increased over time (the area of the envelopes increases in size over time in Figure 4). The primary axis of the ordination is a spatial one along a North-South gradient, with the composition of the hill paddocks being clearly different from the plains paddocks (Figure 5). The primary axis for the ordination of species composition on the plains paddocks also followed a North-South gradient. Paddocks 4A and 4B were compositionally slightly different from the other plains paddocks (Figure 6), which is consistent with their description by Du Toit (2004) as “semi plain/mountain”. The hills paddocks were compositionally distinct from each other (Figure 7) and the primary axis in the ordination follows an

aspect gradient. For both the plains and the hills paddocks there was a directional shift in the ordinations away from Bare Ground (i.e. toward increased cover)

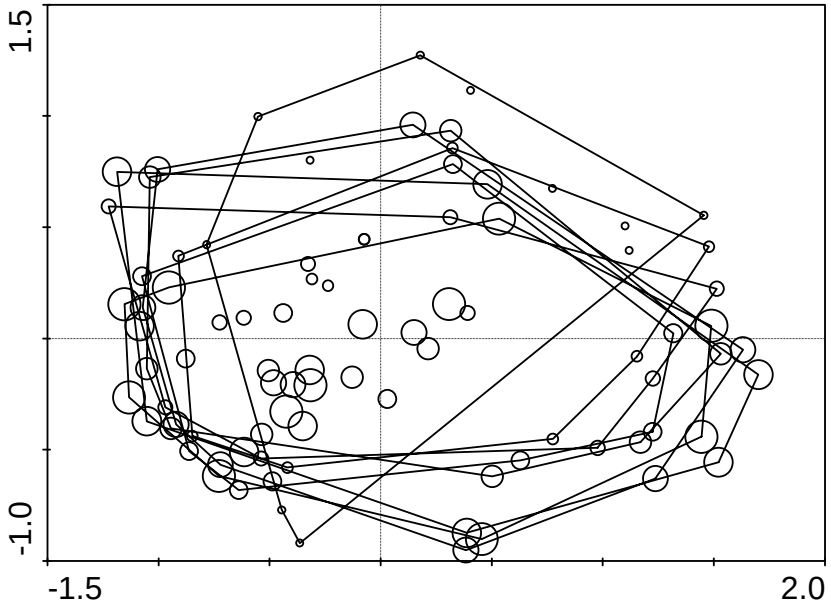

Figure 4. Non-metric multidimensional scaling ordination of species composition in all paddocks in all years grouped according to year (Boesmanskop, Grootfontein). Markers are scaled from smallest (2007) to largest (2015)

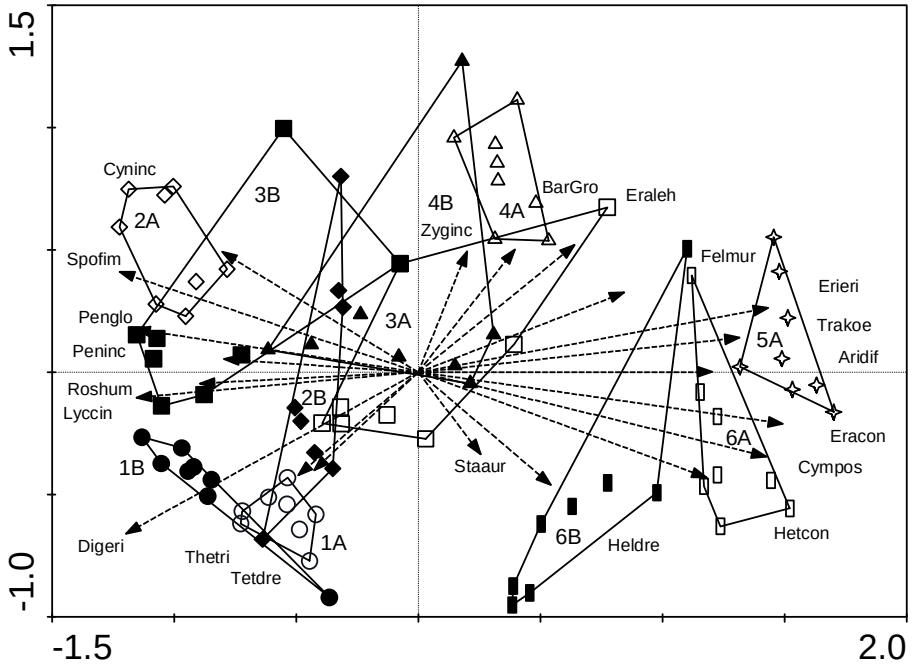

Figure 5. Non-metric multidimensional scaling ordination of species composition of all paddocks at Boesmanskop from 2007 to 2015. Codes are the first three letters of the genus and the species (see Appendix 1); Bargro = bare ground

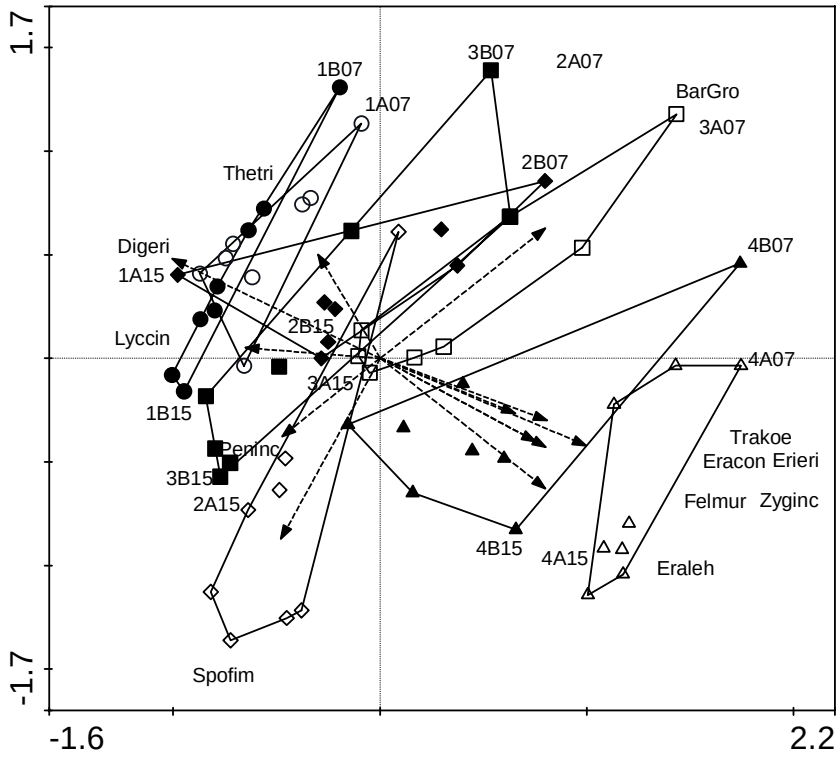

Figure 6. Non-metric multidimensional scaling ordination of species composition of plains paddocks at Boesmanskop from 2007 to 2015. Codes are the first three letters of the genus and the species (see Appendix 1); Bargro = bare ground

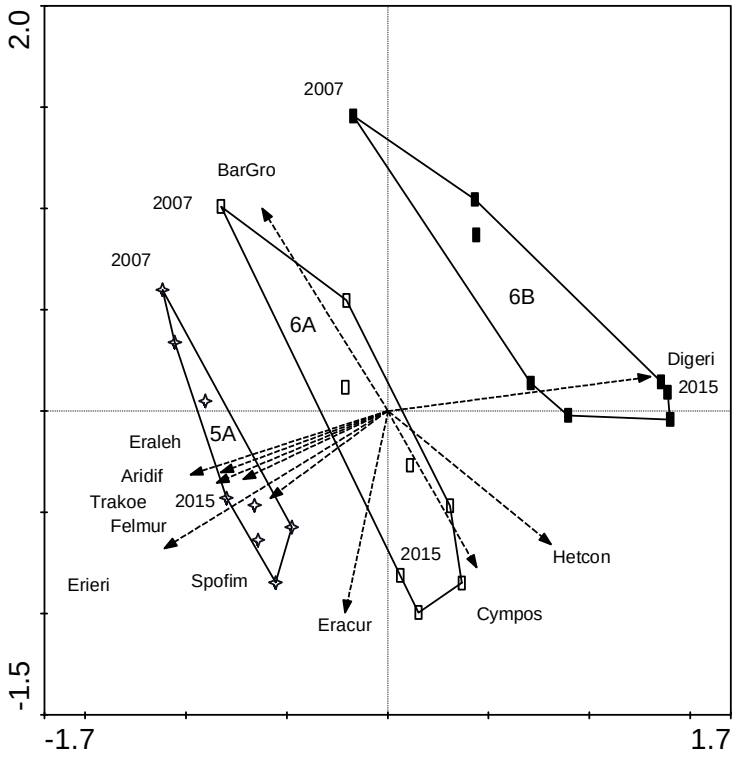

Figure 7. Non-metric multidimensional scaling ordination of species composition of hill paddocks at Boesmanskop from 2007 to 2015. Codes are the first three letters of the genus and the species (see Appendix 1); Bargro = bare ground

Growth forms

Grasses were the most dominant growth form on both the plains and the hills (

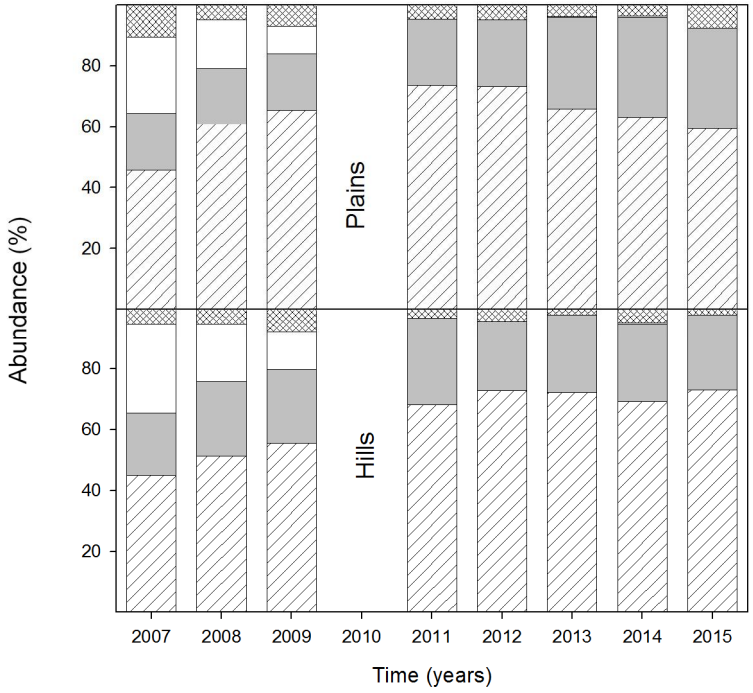

Figure 8), followed by dwarf shrubs. Bare ground declined significantly to approximately 0% by 2011 (Figure 10). On the hills, grasses increased significantly in abundance, while on the plains this was true for dwarf shrubs (Figure 9).

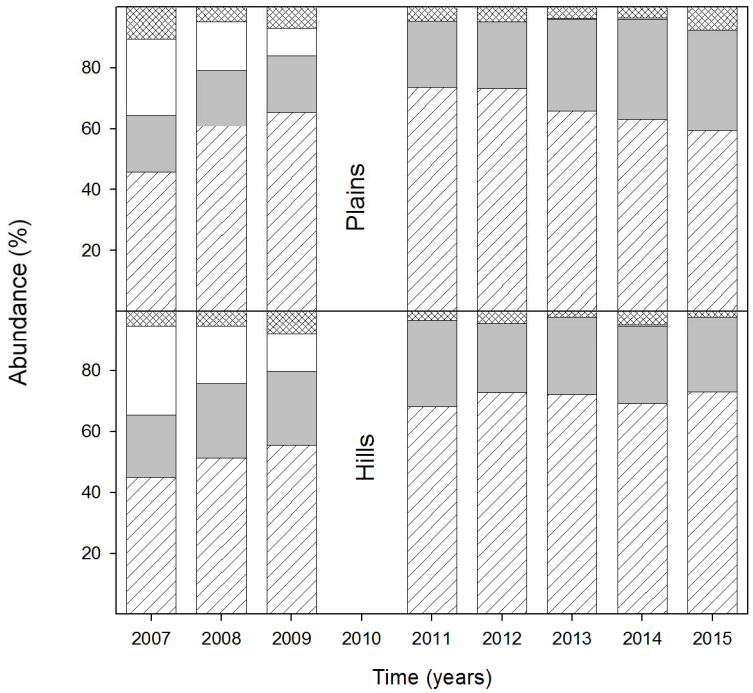

Figure 8. Stacked area bar graph showing the relative abundance of grass (diagonal stripes), dwarf shrubs (grey), bare ground (white) and other (cross-hash) growth forms for plains and hills at Boesmanskop, Grootfontein

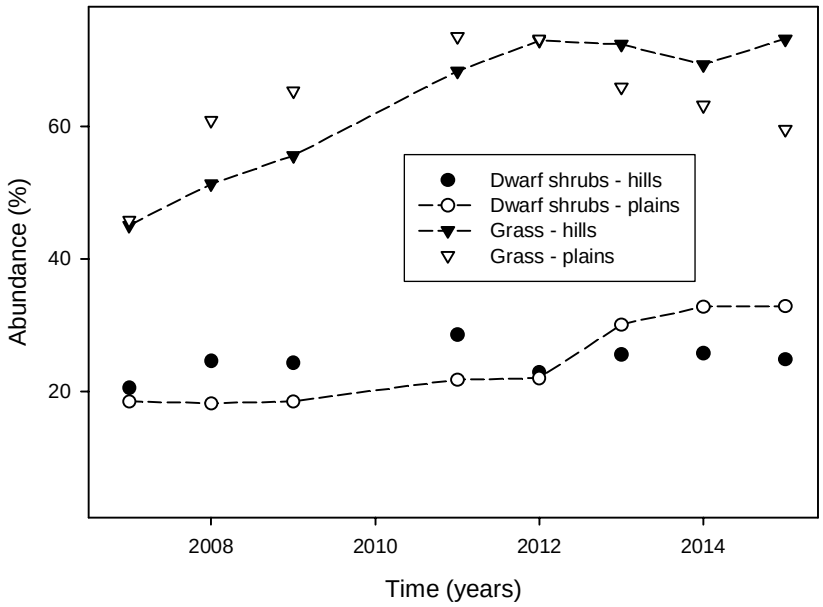

Figure 9. Abundance of the two dominant growth forms (perennials; dwarf shrubs and grasses) for hills and plains at Boesmanskop. Lines highlight those trends that have statistically significant linear regressions ($F_{1,7}$>36; P≤0.001)

Species

The five most abundant species in each paddock accounted for between 46 and 78% of all plants (Table 1). The perennial grass *Digitaria eriantha* was one of the top five most common species in all paddocks, and was usually the most abundant species. The large perennial grass *Cymbopogon pospischilii* was common on the hills paddocks and absent on the plains. The perennial dwarf shrubs *Pentzia globosa* and *Pentzia incana* were common in some of the plains paddocks.

On the hills 92 species were encountered of which 51 were dwarf shrubs and 18 were perennial grasses. The grasses *Eragrostis curvula* subsp *conferta* and *D. eriantha* were co-dominant (each 16%) followed by the shrub *Eriocephalus ericoides* (10%) and *C. pospischilii* (8.2%). The grasses *D. eriantha* and *Heteropogon contortus* and the shrub *E. ericoides* increased significantly over time. On the plains 91 species were encountered of which 44 were dwarf shrubs, 17 were perennial grasses, and 5 were annual herbs. The grasses *D. eriantha* (27%), *Sporobolus fimbriatus* (13%) and *Themeda triandra* (7.6%) were most common, followed by the shrub *P. globosa* (6.6%).

Table 1. Five most abundant species in each paddock at Boesmanskop (data from 2007 to 2015 pooled). Codes are the first three letters of the genus and the species (see Appendix 1)

SppCode	**1A**	**1B**	**2A**	**2B**	**3A**	**3B**	**4A**	**4B**	**5A**	**6A**	**6B**
Cympos									7.7	9.1	7.9
Cyninc			11.5					6.7			
Digeri	40.3	32.7	23.0	36.6	26.4	27.9	7.7	25.2	7.2	11.7	28.9
Eracon	3.7				6.3			7.6	20.4	11.2	16.5
Eraleh							9.5				
Erieri				5.8	5.7		10.1	8.9	14.5	12.3	
Felmur									6.6		
Hetcon										5.2	5.0
Lyccin	3.2										
Penglo		8.2	7.8	7.8		14.0					
Peninc		6.4	7.1	3.7		5.3					
Spofim	9.3	12.1	29.0	6.5	8.0	13.8	11.9	12.2			
Thetri	17.9	18.7			8.0	4.8	7.3				3.3
Total	**74.4**	**78.1**	**78.4**	**60.4**	**54.4**	**65.7**	**46.5**	**60.5**	**56.3**	**49.5**	**61.6**

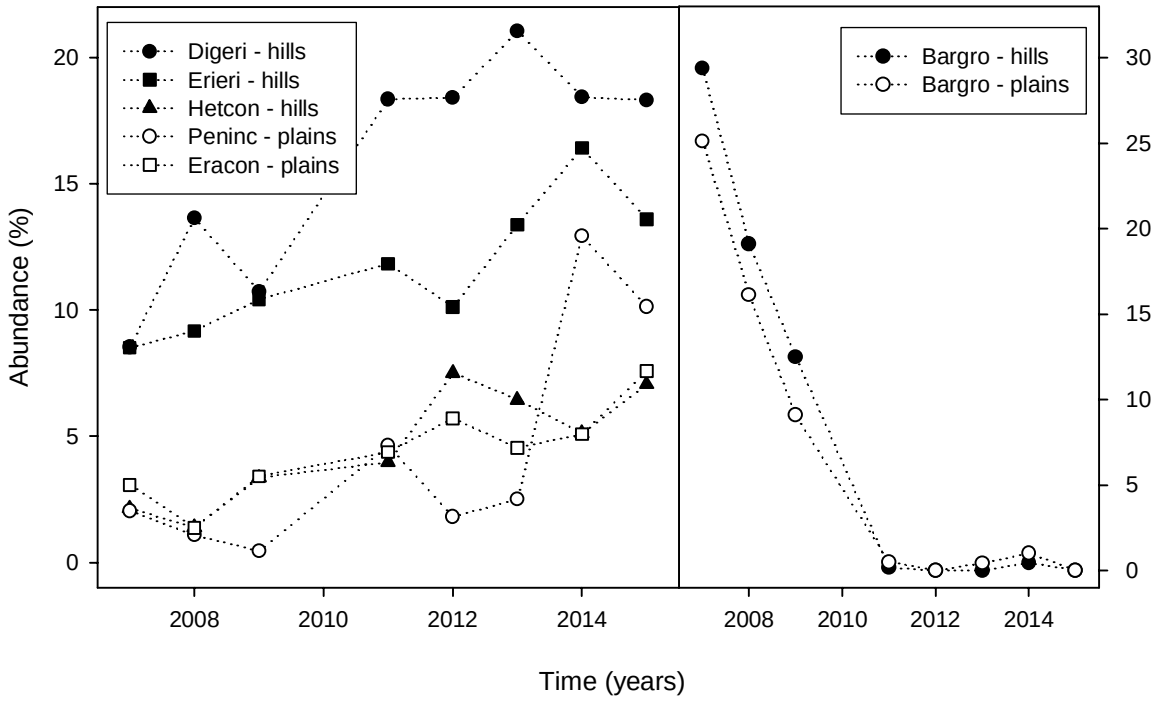

Figure 10. Species (and bare ground) that changed significantly in abundance over time at Boesmanskop (all $F_{1,7}$>16; P<0.007 except for Peninc: $F_{1,7}$=7.4; P=0.03). Codes are the first three letters of the genus and the species (see Appendix 1); Bargro = bare ground

DISCUSSION

Species composition at Boesmanskop varies spatially across the trials with vegetation communities on the hills being distinct from those on the plains. Vegetation is predominantly grassy in terms of cover, though there are more species of dwarf shrub than of grass. The good annual rains from 2007 to 2013 correlate with a decrease in the amount of bare ground (i.e. an increase in cover). On the hills, bare ground appears to have been replaced by the grasses *D. eriantha* and *H. contortus* and the shrub *E. ericoides*, while on the plains the significant increases of *P. incana* and *E. curvula* var *conferta* account for only some of the reduction in bare ground. On the plains, therefore, many species may have contributed to the loss of bare ground, even though these are statistically difficult to identify.

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Appendix 1. Species at Boesmanskop. "Abun" = average abundance over all sites over all years; '-', '---', '+' and '+++' indicate small or large decreases or increases over time, respectively, whether or not these are statistically significant.

Life form and species	Abun	Slope
Annual cyperoid herb		
Bulbostylis humilis	0.12	-
Annual herb		
Chenopodium glaucum	0.05	
Conyza bonariensis	0.13	
Conyza canadensis	0.00	
Hermannia coccocarpa	0.03	
Salsola kali	0.02	
Annual or biennial grass		
Aristida congesta	0.28	+
Chloris virgata	0.08	
Perennial cyperoid herb		
Cyperus capensis	1.12	---
Perennial dwarf shrub		
Amphiglossa triflora	0.03	
Berkheya angustifolia	0.00	
Blepharis capensis	0.01	
Blepharis mitrata	0.01	
Chrysocoma ciliata	0.02	
Dimorphotheca cuneata	0.06	
Eriocephalus ericoides	5.78	+
Eriocephalus spinescens	0.77	+
Eriocephalus spp	0.02	
Felicia fascicularis	0.04	+
Felicia filifolia	0.11	+
Felicia muricata	2.00	+
Galenia procumbens	0.37	-
Gnidia polycephala	0.00	
Helichrysum dregeanum	0.60	-
Helichrysum lucilioides	0.01	
Helichrysum pentzioides	0.01	
Helichrysum rutilans	0.01	
Helichrysum zeyheri	0.29	+
Hermannia cuneifolia	0.02	
Hermannia desertorum	0.03	
Hermannia filifolia	0.03	
Hermannia linearifolia	0.01	
Hermannia multiflora	0.01	
Hermannia pulchella	0.01	
Indigofera denudata	0.01	
Indigofera nigromontana	0.05	
Jamesbrittenia atropurpurea	0.01	
Jamesbrittenia filicaulis	0.05	-
Justicia cuneata	0.00	
Limeum aethiopicum	0.02	-
Melolobium candicans	0.11	
Melolobium microphyllum	0.06	
Nenax cinerea	0.06	-
Nenax microphylla	0.18	+
Osteospermum armatum	0.11	
Osteospermum leptolobum	0.06	-
Pegolettia retrofracta	0.02	+
Pelargonium ramosissimum	0.01	
Pentzia globosa	4.90	+
Pentzia incana	2.83	+++
Pentzia pinnatisecta	0.13	+
Pentzia punctata	0.01	
Pentzia sphaerocephala	0.14	-
Pentzia spinescens	0.00	
Phymaspermum parvifolium	0.60	+
Plinthus karooicus	0.03	
Pteronia glauca	0.44	+
Pteronia sordida	0.27	-
Pteronia tricephala	0.15	+
Rosenia humilis	0.71	+
Salsola calluna	0.45	+
Selago geniculata	0.58	+
Selago saxatilis	0.50	+
Stachys aurea	0.63	-
Stachys rugosa	0.13	
Tripteris sinuata	0.19	
Wahlenbergia albens	0.13	+
Wahlenbergia tenella	0.03	-
Zygophyllum incrustatum	0.59	+
Zygophyllum microphyllum	0.01	
Perennial parasitic dwarf shrub		
Thesium hystrix	0.05	-
Perennial fern		
Cheilanthes eckloniana	0.04	-
Perennial grass		
Aristida diffusa	2.02	-
Cymbopogon pospischilii	2.38	+
Cynodon dactylon	0.11	
Cynodon incompletus	2.95	---
Digitaria eriantha	24.32	+++
Enneapogon scoparius	0.08	-
Eragrostis bicolor	0.20	+
*Eragrostis conferta**	6.85	+++
Eragrostis curvula	1.45	+
Eragrostis lehmanniana	2.43	+
Eragrostis obtusa	0.29	-
Eustachys paspaloides	0.14	+
Heteropogon contortus	1.28	+
Hyparrhenia hirta	0.11	+
Melica decumbens	0.01	
Oropetium capense	0.04	
Sporobolus fimbriatus	9.72	+++
Tetrachne dregei	0.94	+
Themeda triandra	6.32	---
Tragus koelerioides	1.78	+
Perennial herb		
Aptosimum procumbens	0.01	
Dimorphotheca zeyheri	0.05	
Gazania jurineifolia	0.01	
Hermannia pulverata	0.04	
Indigofera alternans	0.05	
Salvia stenophylla	0.07	
Perennial geophytic herb		
Moraea pallida	0.01	
Moraea polystachya	0.02	
Oxalis depressa	0.01	
Perennial shrub		
Asparagus africanus	0.05	+
Asparagus suaveolens	0.01	
Lycium cinereum	1.60	+
Perennial succulent		
Mestoklema tuberosum	0.07	-
Ruschia grisea	0.06	
Trichodiadema pomeridianum	0.19	-
Perennial succulent dwarf shrub		
Hertia pallens	0.01	
Kleinia longiflora	0.03	
Ruschia intricata	0.50	-
Sarcocaulon salmoniflorum	0.05	+
Perennial succulent herb		
Senecio radicans	0.01	
Tripteris aghillana	0.55	+
Perennial tree or large shrub		
Diospyros austro-africana	0.00	
Searsia erosa	0.01	

* = *Eragrostis curvula* subsp *conferta*