

## Functional responses of South African rangelands in contrasting tenure systems

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**Abstract.** Land degradation in South African rangelands has frequently been studied in the context of tenure systems, because both governmental policy and range management practices were historically implemented in contrasting forms. We compared the functional response of vegetation along grazing gradients between a communal (CU) and commercial (CO) farming areas. One transect was established per farm from the waterpoint to a mid-field position. Six equally spaced plots (5 m × 5 m) were set up along each transect. Using a taxon-free sampling procedure, we recorded the response of 15 community-aggregated plant functional traits (CPFT) in: (1) mature standing biomass; and (2) after four weeks' regrowth following clipping. Additionally, species identity was recorded. Grazing on CU was continuous and stocking rate not controlled, while CO applied rotational grazing with recommended stocking rates. From the results, CPFT differences were not significant (Student's *t*-test,  $P < 0.01$ ) between tenure systems. A principal component analysis of CPFT showed largely overlapping functional responses in the two tenure systems in the case of mature standing biomass, while the functional response of regrowing vegetation was clearly separated in the ordination space. Communal rangelands had twice the species richness of commercial farms. We concluded that, from a functional perspective, communities under different tenure systems were similar. However, the functional response of vegetation regrowth might be different as well as the ecological services provided (biodiversity).

**Keywords:** Community-aggregated plant functional traits, grazing gradient, taxon-free method.

### Introduction

In his famous and well received paper, Hardin (1968) predicted that a management of natural resources as common property would lead to an unbiased destiny of total deterioration. However, numerous unfenced rangelands have been utilized by pastoral people for centuries, and this continues to be the dominant land-use in most grasslands of the world (Davies and Nori 2008). Land degradation in the rangelands of South Africa (RSA) is a complex process influenced by a wide spectrum of physical and environmental conditions as well as particular socio-economic conditions. The latter were shaped by: (1) the history of land allocation; (2) governmental care; and (3) political decisions in the context of land tenures (Meadows and Hoffman 2002). The tenure system itself developed different grazing systems. In communal grazing areas continuous grazing and uncontrolled stocking rates are applied while in contrast, commercial farms predominantly practice rotational grazing and adjust stocking rates in accordance to the carrying capacity. Thus, land tenure as a predictor for grazing management has been blamed as the main cause for the generally accepted view that the vegetation structure on communal rangelands in the Thaba Nchu region is undergoing degradation (Snyman 2011). However, the topic of vegetation dynamics has not been extensively studied.

The increased interest in understanding ecosystem functioning has further enhanced the development of functional approaches in ecological and rangeland studies. Plant functional traits at the community level (CPFT) of species-rich rangelands is a promising tool to characterize energy and nutrient fluxes, to predict vegetation responses to grazing, and to investigate indirect effects of grazing in core ecosystem functions (*i.e.* water dynamics, litter decomposition). Furthermore, characterization of vegetation with soft traits permits comprehensible plant strategies to be summarized for species-rich communities (Hunt *et al.* 2004). An increased functional understanding of the interconnection between grazing system on the one hand and vegetation functioning and ecological services on the other is highly important to ensure sustainable management and to support stakeholders and decision makers.

Our goal was to investigate if land tenure of rangelands in South Africa, as an indicator of grazing regime, triggers distinctive vegetation functioning as a response to grazing.

### Methods

#### Study area

The study was conducted in Thaba Nchu, RSA (29°13'S; 26°47'E). The climate is semi-arid with 560 mm mean

annual rainfall. Predominant soils are lixisols, the vegetation is dominated by perennial C<sub>4</sub> grasses such as *Themeda triandra* and *Eragrostis* spp. We selected four representative farms, two in communal grazing areas (CU) and two on commercial farms (CO). At each study site, one transect along the piosphere caused by animal grazing was identified, starting from a single permanent waterpoint and ending at average field conditions of vegetation. Along each transect, six plots (5 m x 5 m) were equally spaced and designated as position closest to (P1) and farthest from (P6) the water point.

### Sampling

A trait-transect sampling procedure (taxon-free method) was applied (Gaucherand and Lavorel 2007), and for each plot 26 mature tillers, such as flowered stems and rooted individual units in grasses, were measured (Table 1). Additionally, the identity of each species was registered. After sampling in mature biomass (12 CPFT were measured – Table 1), trait-transects were clipped. Four weeks after clipping, re-sampling was conducted for 3 CPFT (Table 1). Values of PFT were averaged crosswise in each plot to calculate a community value.

### Data Analysis

Differences of CPFT mean values between CU and CO were tested using Student's *t* test ( $P < 0.05$ ) with SPSS Statistics 20 (IBM 2011). We Log<sub>10</sub> transformed L<sub>N</sub>, L<sub>SLA</sub>, T<sub>N</sub>, T<sub>W</sub> and T<sub>WRE</sub> to normalise the data. We performed a principal component analysis (PCA) with CANOCO for Windows 4.5 (Ter Braak and Šmilauer 2002) with the settings: (1) not standardised by samples; and (2) centred and standardised by CPFT. A multi-response permutation procedure (MRPP) was performed with PC-ORD (Version 6) (McCune and Mefford 2011) as an alternative approach to assess functional differences on SB between tenure

systems. We grouped samples of two transect positions per tenure system as near (1 and 2), middle (3 and 4) and far (5 and 6). Multiple comparisons based on relative Euclidean distances were performed. We listed species per plot.

### Results

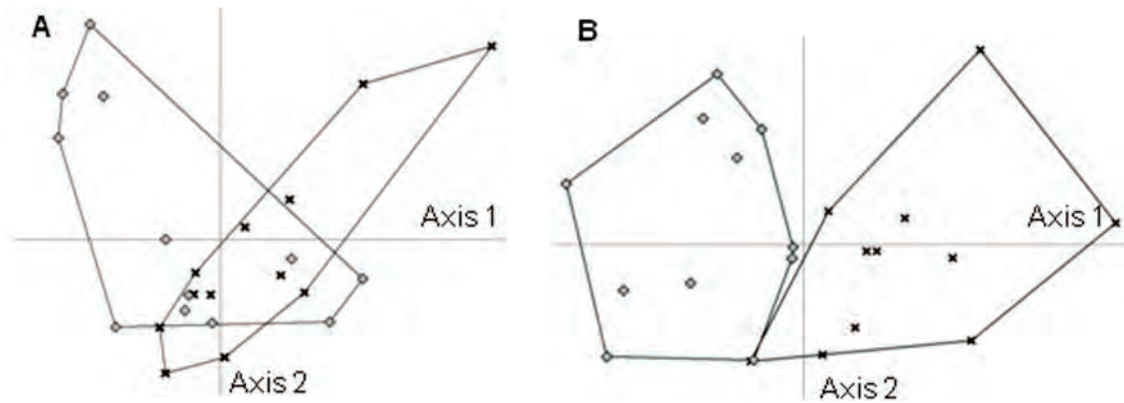
CPFTs were not significantly different between tenure systems (Table 1), except T<sub>WRE</sub>, which was found to be lower in CU (22.9 mg) than in CO (42.2 mg). The ordination diagrams of PCA display the distribution of plots accounting for CPFT measured on the standing biomass (Fig. 1A) and on the regrowth (Fig. 1B). When CPFT were measured on standing biomass (Fig. 1A), a common area in the centre of the ordination diagram was occupied by most of the sampled plots, irrespective of tenure system. In contrast, results from the regrowth indicated a complete separation of plots by land tenure (Fig. 1B), except in the case of two plots that were deleted from the figure for an easier view.

MRPP results are presented in Table 2. The first section of the table shows the comparison of grouped transect positions between tenure systems. Positions near the waterpoints (1 and 2) and middle positions (3 and 4) exhibited no significant differences, whereas positions far from water points (5 and 6) did. The second section of the table presents comparisons of different positions along grazing gradients. Positions near to waterpoints were significantly different from more distant positions (middle and far). However, non-significant differences were identified among middle positions and far positions. Similar differences were identified within positions of communal and privately owned lands.

Mean species richness was similar in plots of CU (4.5) and CO (4.0). However, total number of species recorded in CU (30) was higher than in CO (14). Only two species were exclusively present in CO.

**Table 1. Community-aggregated plant functional traits (CPFT) measured on standing biomass (SB) and regrowth (RE), their description, abbreviations, measurements units. Test of Normal distribution and mean difference of CPFT between communal and private farms. NDF is neutral detergent fibre, F is statistic F, P probability, \* is  $P < 0.05$ , and \*\* is  $P < 0.01$ .**

Measured material	Description	Abbreviation	Unit	Levene's Test			Student 't' test	
				F	P		P	
Leaf, SB	Readings	L <sub>SPAD</sub>	SPAD	2.95	0.10	ns	0.14	ns
	Leaf area	L <sub>a</sub>	cm <sup>2</sup>	1.80	0.19	ns	0.21	ns
	Leaf carbon content	L <sub>C</sub>	mg/g	1.53	0.23	ns	0.30	ns
	Leaf carbon to nitrogen ratio	L <sub>C:N</sub>		0.10	0.76	ns	0.29	ns
	Leaf nitrogen content	L <sub>N</sub>	Log <sub>10</sub> (mg/g)	0.17	0.69	ns	0.28	ns
	Leaf number per tiller	L <sub>n</sub>	No./tiller	3.95	0.06	ns	0.06	ns
	Specific leaf area	L <sub>SLA</sub>	Log <sub>10</sub> (m <sup>2</sup> /kg)	1.28	0.27	ns	0.17	ns
Tiller, SB	Tiller carbon content	T <sub>C</sub>	mg/g	1.40	0.25	ns	0.08	ns
	Tiller cell wall content (NDF)	T <sub>CW</sub>	mg/g	0.05	0.82	ns	0.06	ns
	Tiller height	T <sub>h</sub>	cm	9.53	0.01	**	0.07	ns
	Tiller nitrogen content	T <sub>N</sub>	Log <sub>10</sub> (mg/g)	0.00	0.97	ns	0.07	ns
	Tiller weight	T <sub>w</sub>	Log <sub>10</sub> (mg)	2.56	0.12	ns	0.18	ns
Leaf, RE	Regrowth	L <sub>nRE</sub>	/tiller	2.02	0.17	ns	0.09	ns
Tiller, RE	Tiller weight on the regrowth	T <sub>wRE</sub>	Log <sub>10</sub> (mg)	1.28	0.27	ns	0.00	**
	Tiller height on the regrowth	T <sub>hRE</sub>	cm	0.10	0.75	ns	0.16	ns



**Figure 1.** Similarities of South African rangeland vegetation based their community-aggregated plant functional traits (CPFT). Ordination diagrams from principal component analyses show plots from communal grazing areas (x) and commercial farms (♦). A: CPFT data measured on the standing biomass, B: data measured in the regrowth four weeks after clipping.

**Table 2.** Results of multi-response permutation procedure (MRPP) on grouped transect positions on communal (CU) and privately owned (CO) rangelands in Thaba Nchu, South Africa. A is statistic A chance-corrected within-group agreement as  $\log_{10}$ , and T is test statistic T describe separation between groups.

Multiple comparisons	CU	CO	P		A	T
Near CU vs Near CO	1,2	vs 1,2	0.838	ns	8.89E-01	-0.031
Middle CU vs Middle CO	3,4	vs 3,4	0.13	ns	-1.04E+08	0.0566
Far CU vs Far CO	5,6	vs 5,6	0.008	**	-3.72E+08	0.172
Near CU vs Middle CU	1,2 vs 3,4		0.042	*	-2.14E+08	0.0704
Near CU vs Far CU	1,2 vs 5,6		0.044	*	-2.14E+08	0.0697
Middle CU vs Far CU	3,4 vs 5,6		0.513	ns	2.89E+08	-0.009
Near CO vs Middle CO	1,2	1,2 vs 3,4	0.015	*	-3.19E+08	0.174
Near CO vs Far CO	1,2	1,2 vs 5,6	0.001	**	-5.77E+08	0.3004
Middle CO vs Far CO	3,4	3,4 vs 5,6	0.442	ns	2.24E-01	-0.013

**Discussion**

We compared vegetation communities on rangelands under different tenures systems. The analyses account for varied functional aspects of vegetation related to: (1) radiation exposure,  $L_a$  and  $L_n$ , as leaf number and area added to the photosynthetic area per tiller; and (2) photosynthetic capacity (*i.e.*  $L_{SLA}$ ,  $L_{SPAD}$ ,  $L_C$ ,  $L_{C:N}$  and  $L_N$ ) where higher ratios of leaf area per mass and less structural leaf components are indicative of higher photosynthetic rates (Wright *et al.* 2004), as well as higher leaf greenness (Kantety *et al.* 1996). Leaf greenness and leaf nitrogen concentration are directly associated to chlorophyll content (Gaborcik 2003). We further included traits of (3) standing biomass accumulation (*i.e.*,  $T_h$  and  $T_w$ ) and (4) phenology ( $T_C$  and  $T_{CW}$ ). Our results showed that land tenure did not prove to be a determining factor to differentiate plant communities according to the functional characteristics of mature standing biomass (Fig. 1A). According to CPFTs, plots were functionally similar. However, a contrasting result occurred with traits measured on regrowth, although fewer traits were considered. CPFTs might differ between mature and regrowth biomass because of a different regenerative strategy (Lavorel *et al.* 1997; Violle *et al.* 2012). To the trait-transect method, we added records of species identity which allowed us to get a proxy for richness, another synthetic attribute of plant communities.

We found larger species richness on communally managed rangelands because of species turnover along grazing gradient. At landscape scale, this may boost the functional vegetation heterogeneity and sequentially increase livestock and rangeland productivity (Fynn 2012).

**Conclusions**

We conclude that the functioning of mature vegetation is not different among CU and CO in Thaba Nchu, RSA. This could point to the possibility that primary productivity is not necessarily affected by grazing management as has been reported elsewhere (Briske *et al.* 2008). However, our results suggest that vegetation functioning under grazing might exhibit a different immediate response to clipping and eventually to animal defoliation. This might have certain implications for animal production and management. A further study measuring the regrowth response along the growing season is proposed for future research.

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