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Evaluation of potential indicators for payment of environmental services on the impact of rehabilitation of degraded rangeland sites

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An understanding of the response of indicators of rangeland degradation following rehabilitation is essential to the successful implementation of the Payment for Environmental Services initiative that is currently being developed in the communal rangelands of the Drakensberg mountains of South Africa. We evaluated the following four potential indicators of rangeland degradation: Range condition, basal cover, species diversity, and soil fertility. The indicators were measured in degraded and rehabilitated sites at Okhombe in Northern KwaZulu-Natal, South Africa. Two transects were established at each site for basal cover and species composition. Soil samples were collected from each site and their elements analysed. The results revealed that differences between the rehabilitated and degraded sites can be quantified using indicators of range condition, basal cover, and species diversity. There were highly significant differences in certain soil properties (that is, P 11.36 mg/kg, K 0.47 cmol/kg, pH 4.20, OC 6.33% and N 0.70%) after rehabilitation. Based on these results, we argue that these indicators have the potential to be used in monitoring and certifying the delivery of watershed services at a local level in this communal rangeland.

Key words: Decreaser and increaser, species diversity, soil fertility, rangeland condition.

INTRODUCTION

Rangeland degradation remains a topical issue because of its adverse impact on soil, water and vegetation. It affects the quantity and quality of the natural vegetation available for grazing (Passmore and Brown, 1991; Snyman and Du Preez, 2005; UNCCD, 1995), and negatively affects the people who rely on these resources for their livelihoods. Since natural vegetation species are well adapted to growing in specific environmental conditions, their relative abundance is reduced when environmental conditions change. Due to this sensitivity to specific conditions, changes in vegetation species composition can be used as indicators of rangeland degradation (Mansour et al., 2012). This degradation and the development of rehabilitation techniques, specifically in arid, semi-arid, and sub-humid areas, have become pressing concerns in terms of the sustainable management of rangelands (Passmore and Brown, 1991; Snyman and Du Preez, 2005). Intensive livestock grazing, agricultural activities and deforestation are considered to be the main causes of soil degradation

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(Wu and Tiessen, 2002). Other factors that contribute towards rangeland degradation are erosion and low soil fertility. Declining soil fertility is recognised as a major cause of low rangeland productivity (Oluwole and Dube, 2008). In a China-based study, soil fertility indicators of rangeland degradation were cation exchange capacity (CEC), organic carbon (OC), and total N (Wu and Tiessen, 2002). Soil acidity (pH < 4) reduced the rangeland's vegetative growth, flowering, and forage nutritive content. Oluwole and Dube (2008) found that higher quantities of Na (2160.8 mg/kg^{-1}), Ca (3618.1 mg/kg^{-1}), and low organic carbon (<13.0 mg/kg^{-1}) were associated with a highly degraded site in the Eastern Cape of South Africa.

South Africa's rangelands are a critical resource as they supply local communities with a range of provisioning services which include water and grass for wildlife and livestock. Rangeland occupies more than 70% (1,219,000 km^2) of South Africa's land surface and is used almost exclusively for pastoral production (Snyman, 2003). These rangelands are divided in two groups, namely communal and commercial rangelands; a classification based on the tenure system, the quantity and quality of forage production, and livestock production techniques (Hoffman and Todd, 2000; Tainton, 1999).

In the past few decades the monitoring and evaluation of rangeland degradation in South Africa has primarily focused on commercial rangeland (Shackleton, 2000) which means that communal rangeland has not yet enjoyed the same degree of attention (Hoffman and Todd, 2000; Trollope, 2011; Wessels et al., 2004). Communal rangeland occupies roughly 13% of the total agricultural land in South Africa of which 4.8% (5.8 million ha) has been identified as degraded (Wessels et al., 2004). Communal rangeland is one of the land areas most severely affected by high human populations, increased numbers of livestock, increased run-off, poor water infiltration, severe soil erosion, loss of grass cover (particularly palatable grazing species), and poor land use management (Hoffman and Todd, 2000). The continued degradation of communal rangeland is a major threat to livestock production, biodiversity, and human livelihoods (Hoffman and Todd, 2000). Several agronomic and ecological techniques have therefore been developed over the past two decades to evaluate and monitor range conditions based on the relative abundance and distribution of increaser and decreaser species. The techniques include weighted palatability composition methods (Barnes et al., 2007), the benchmark method (Foran et al., 1978), the ecological index (Vorster, 1982), the key species method (Mentis, 1981), the weighted key species method (Hurt and Hardy, 1989), and the use of degradation gradients (Bosch and Gauch, 1991). These methods have achieved differing degrees of success in evaluating and monitoring range condition over small geographic areas (Jordaan et al., 1997; Trollope, 1990).

The benchmark technique, whereby the species composition of a particular site is compared to that of a benchmark where the range is in excellent condition, offers an economical and effective solution for producing timely and accurate information that assesses South Africa's rangelands (Foran et al., 1978; Tainton et al., 1980) and can also be applied to different ecosystems (Hardy et al., 1999). There is increasing interest in predicting the environmental factors which govern the dynamics of communal rangeland. This desire for prediction is driven by the pressing need to improve vegetation composition in the rangelands and requires a good understanding of the environmental factors that cause change (Mapiye et al., 2008; Snyman, 1998). Furthermore, knowledge of how to quantify the effects of communal range management on water resources is required to understand the links between grazing management and hydrological benefits (Everson et al., 2007).

Okhombe is a communal rangeland characterised by soil erosion, rills, gullies, and the dominance of unpalatable grass species throughout its foot, mid, and upper slopes (Von Maltitz, 1998). Up-to-date information about range conditions based on vegetation species and soil properties is required for effective and sustainable range management. Human interventions such as payment for environmental services (PES) could play a significant role in establishing effective rehabilitation techniques for rangeland management in communal areas. PES, a project involving a community-based monitoring system, was launched in the Okhombe communal rangeland in 1999 to promote the effective management of natural resources to improve rangeland productivity in communal lands (Everson et al., 2007). Much success has been achieved through soil erosion prevention techniques such as stone lines, stone packs, strips of kikuyu and vetiver grass, and swales (Everson et al., 2007). These techniques are considered important in rehabilitation interventions and rangeland management (Everson et al., 2007; Peden, 2005) because they have several advantages such as stabilising loose soil, decreasing overland flow and run-off, and increasing soil organic matter and phosphorus. At present, the available information on communal rangeland is not enough for a detailed understanding of the effect of land use practices on natural resources. If PES is to be effective there is an urgent need to develop appropriate indicators of rangeland quality. Identifying these indicators will require research at community, local, and national levels. These indicators should be consistent, measured (rank and scale or rating), classifiable (quantifiable), and descriptive. The objective of this study was to evaluate which potential indicators (range condition, basal cover, species diversity, and soil nutrients namely phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), pH, zinc (Zn), manganese (Mn), copper (Cu), organic matter (OC), and nitrogen (N) would be most suitable for determining the success of rangeland rehabilitation for PES programmes.

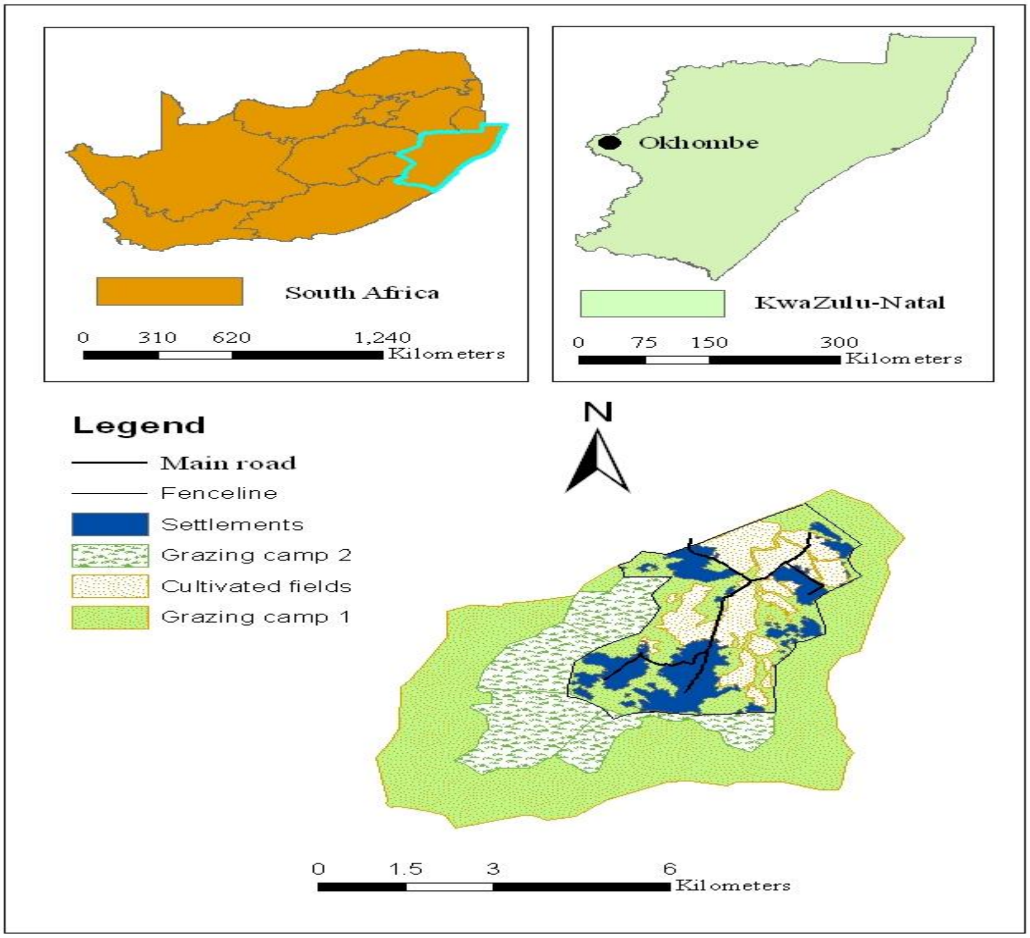

Figure 1. Location of study area in the KwaZulu-Natal province of South Africa.

MATERIALS AND METHODS

Study area

The study was conducted in the Okhombe communal rangelands (latitude 28°30'S to 30°30'S and longitude 28°30'E to 29°30'E) which cover an area of 200 km^2. Okhombe is a ward that comprises six sub-wards, namely Mpameni, Mahlabathini, Ngubhela, Oqolweni, Sgodiphola, and Enhlannokhombe. The selected area lies in the foothills of the northern Drakensberg mountains in the province of KwaZulu-Natal (Figure 1), and its altitude varies from about 1,780 to 1,840 m above sea level. Rain falls almost exclusively during summer (October to March), with an average of between 800 mm and 1,000 mm per year (Dollar and Goudy, 1999). The mean maximum monthly temperature varies from 11.5 to 16°C, with a minimum monthly mean of 5°C for June and July (Temme, 2008). Soil materials are basalt-derived silty clays in the low areas, whilst shales, sandstone, and mudstone prevail on the slopes and plateau (Everson et al., 2007). Soils are classified as lateritic red and yellow earths (Temme, 2008) and are typically highly leached, acidic, and unstructured. The vegetation is predominantly grassland with some patches of forest as well as shrubs (Mucina and Rutherford, 2006). In the communal areas the common species are: *Hyparrhenia hirta*, *Eragrostis racemosa*, *Eragrostis curvula*, *Eragrostis plana*, *Digitaria tricholaenoides*, *Paspalum dilatatum*, *Paspalum notatum*, *Aristida diffusa*, *Harpochloa falx*, *Sporobolus africanus*, and *Melinis repens* (Mucina and Rutherford, 2006). The absence of effective management strategies with regard to the natural resources of communal rangelands has negative effects on a land's productivity (Peden, 2005). Accordingly, large parts of the study area are severely degraded which have resulted in the loss of vegetation cover, increased run-off, poor water infiltration, and severe soil erosion (Everson et al., 2007). The Okhombe LandCare Project was part of the South African National LandCare Programme initiated in 1999 to rehabilitate degraded areas within the communal rangelands of Okhombe (Everson et al., 2007).

Data collection

The absence of effective management strategies within the Okhombe communal rangeland has resulted in negatively impacted vegetation and soil properties. Four indicators, namely range condition, basal cover, species diversity, and soil fertility were therefore selected to assess the current range condition.

Range condition assessment

Since range condition is an important indicator of grazing potential, the range condition was assessed in adjacent rehabilitated and degraded sites. During the week of the 3rd to 9th December, 2010, data was collected for the purpose of range condition assessments.

Two transect lines, each 200 m long, were established at each site (degraded and rehabilitated) in each of the two sub-wards. A metal spike of approximately 1.2 m in length was used to record the species. The nearest living plant to the point of the metal spike was identified and recorded for 200 points on each transect. The observed grass species were identified according to their names and the other non-grasses (sedges) were identified as a group called forbs (Tainton, 1999). The range condition was calculated by comparing the species composition of the particular site with that of the benchmark. The benchmark method developed by Foran et al. (1978) and Tainton et al. (1980) was used to assess the range condition in both the degraded and rehabilitated sites. The Bioresource Group 8 (Moist Highland Sourveld Group 8) was applied as a benchmark site because the Okhombe rangeland falls within the same ecological zone (Tainton, 1999). All the identified species in the sample site were classified into their relevant categories, namely decreaser species (the relative abundance of a species decreases when the rangeland is under- or over-utilised) or increaser species. Increaser species increase due to under-utilisation (increaser I), over-utilisation (increaser II), or selective grazing (increaser III) (Tainton, 1999). The range condition score (RCS) was calculated by multiplying the percentage of each species by its grazing value. The range condition was then obtained by dividing the total of the RCS by the reference benchmark site.

Basal cover

Basal cover is considered the most reliable measure for monitoring the herbaceous layer covering the ground in degraded and rehabilitated rangeland (Everson et al., 2007). Grass basal cover is well adapted to specific growth conditions and will increase or decrease dramatically if conditions change (Everson et al., 2007; Hardy and Tainton, 2007). In this study, the distance/diameter method was applied for estimating the basal cover of the soil. The method was thought appropriate to Okhombe's degraded rangeland because the area is characterised by soil erosion, rills, and gullies, which means that measuring the distance between the tuft and the diameter of each tuft was important for determining the erosion potential of run-off from the hilly sites. Basal cover data was collected using a measuring tape and a metal spike. The distance (cm) from the nearest living plant to the point of the metal spike was measured (D), and the basal diameter of the tuft (d) then identified, measured, and recorded for 200 points in each of the degraded and rehabilitated sites where range condition data was collected. Basal cover was calculated using the following equation, developed by Hardy and Tainton (2007):

$$BC = 19.8 + 0.39(D) - 11.87(\log_e D) + 0.64(d) + 2.93(\log_e d) \quad (1)$$

Where BC is basal cover, D is the mean distance (cm) from a point to the nearest tuft, and d is the mean basal diameter (cm) of the tuft.

Species diversity index

Species diversity (species richness) is the number and frequency of a species in a community for a particular place (Beisel and Moreteau, 1997; Shackleton, 2000) and is used as an indicator of rangeland degradation (Metzger et al., 2005; Rutherford and Powrie, 2010). Shannon's diversity index is a nonparametric statistical parameter based on the proportion of species relative (qi) to the total number of that species (Q) (Chao and Shen, 2003; Lande, 1996). The use of Shannon's diversity index was preferred in this study because it is suited to comparing different ecosystems and was applied where the data on range condition and basal cover were collected in degraded and rehabilitated sites during November and December of 2010. A species plot area of 1 m × 1 m was randomly defined where the range condition was being assessed. A total of 100 plots were established; 50 were in the degraded site and 50 were in the rehabilitated site. Species diversity was calculated by considering the number of species per ecological category (decreaser, increaser I, increaser IIa, increaser IIb, increaser IIc, and increaser species III). The equation for computing species diversity is as follows (Shannon and Weaver, 1963):

$$H' = -\sum_{i=1}^{S} \left(\frac{qi}{Q}\right) \log \left(\frac{qi}{Q}\right) \quad (2)$$

Where H' is the Shannon-Weaver diversity index, qi is the fraction of individuals belonging to the i species, Q is the total number of the individual species in the sample, and S is species richness.

Soil assessment

Soil samples were collected at 0 to 15 cm depths using a soil-sampling auger from 100 plots (sampling plot 1 m x 1 m); 50 were in the degraded site and 50 in the rehabilitated site. Soil samples were collected under dry atmospheric conditions, and care was taken to ensure that the sites were representative of their respective ecosystems (rehabilitated and degraded). The labelled bags of soil were stored in dry conditions until transported to the laboratory for analysis. The soil samples were analysed for soil degradation e.g. soil pH $_{(KCl)}$, total N and OC, available P, soluble K, Ca trace elements Mg, Zn, Mn, Cu. The soil pH was measured in soil suspension (1 soil: 5 KCl) using a digital pH-meter with slandered glass electrode. Total N and OC were both measured by mid-infrared spectroscopy (McCarty et al., 2010). Plant available P was estimated by extracting with ammonium bicarbonate solution (0.25 buffered at pH 8.0) and determined calorimetrically (The Non-affiliated soil analysis work committee, 1990). The Total K^+, Ca^{++}, Mg^{++} and trace elements (Cu, Mn and Zn) were determined using electrothermal flame atomic absorption spectrometry (ETAAS) (The Non-Affiliated Soil Analysis Work Committee, 1990). The soil density was measured using a 10 ml scoop.

Data analysis

The data was statistically analysed using one-way ANOVA in the GenStat (version 12) statistical software package (Payne et al., 2009) to determine if there were any significant differences ($P < 0.05$) in soil properties for the rehabilitated (Mpameni and Ngubhela) and degraded (Mpameni and Ngubhela) sites. A paired t-test was used to compare the results for the rehabilitated and degraded sites.

RESULTS

Range condition

The range condition was low in all sites, ranging from 35.4 to 46.7% (Table 1). This was attributed to the loss of palatable decreaser species (0-10%) when compared with the benchmark site (49%), and an increase in increaser III species. However, there was an increase of approximately 10% in the range condition of the rehabilitated sites when compared with the benchmark sites. The lower percentage of increaser III species, particularly *A. diffusa*, accounts for this increase in range quality. The degraded sites of Mpameni and

Table 1. Summary results of range condition and basal cover for each ecosystem (that is, rehabilitated and degraded).

Ecological category	Species	Range condition assessment						
		Grazing value	Benchmark (%)	Benchmark score	Mpameni		Ngubhela	
					Degraded	Rehabilitated	Degraded	Rehabilitated
Decreaser	*Themeda triandra*	10	45	450	0	0	0	10
	Brachiaria serrata	3	1	3	0	0	0	0
	Diheteropogon amplectens	8	1	8	0	0	0	0
	Monocymbium ceresiiforme	6	2	12	0	0	0	0
Sub-total		27	49	473	0	0	0	10
Increaser I	*Alloteropsis semialata*	3	2	6	12	12	18	21
	Trachypogon spicatus	3	2	6	9	9	12	15
	Eulalia villosa	3	1	3	0	3	3	3
	Tristachya leucothrix	9	20	180	63	72	45	81
	Koeleria capensis	3	0	0	0	0	0	0
	Festuca costata	5	0	0	0	0	0	0
	Digitaria tricholaenoides	6	0	0	12	24	12	24
Sub-total		32	25	195	96	120	90	144
Increaser IIa	*Eragrostis capensis*	2	1	2	24	26	28	18
	Heterpogon contortus	6	4	24	48	54	54	66
	Harpochloa falx	2	3	6	0	6	4	6
Sub-total		10	8	32	72	86	86	90
Increaser IIb	*Eragrostis racemosa*	2	1	2	26	26	22	14
	Eragrostis curvula	5	1	5	10	10	15	10
	Hyparrhenia hirta	3	1	3	9	9	3	6
	Eragrostis plana	3	1	3	15	15	18	21
	Eragrostis obtusa	3	0	0	0	0	1	0
	Digitaria mondactyla	2	0	0	2	0	2	2
	Sporobolus africanus	1	0	0	3	0	3	3
	Loudetia simplex	3	0	0	1	1	0	0
Sub-total		22	4	13	66	61	64	56
Increaser IIc	*Microchloa caffra*	1	1	1	1	1	1	2
	Melinis repens	1	0	0	8	8	9	5
	Felicia filifolius	0	0	0	0	0	0	0
	Paspalum dilatatum	7	0	0	7	14	0	21
	Paspalum notatum	3	0	0	3	9	12	6

Table 1. Contd.

	Forbs	0	5	0	0	0	0	0
	Sedges	0	1	0	0	0	0	0
Sub-total		12	7	1	19	32	22	34
	Diheteropogon filifolius	0	2	0	0	0	0	0
	Elionurus muticus	0	5	0	0	0	0	0
Increaser III	*Rendlia altera*	0	0	0	0	0	0	0
	Aristida diffusa	0	0	0	0	0	0	0
Sub-total		0	7	0	0	0	0	0
Grand totals			100	714	253	299	262	334
RC (%)					35.4	41.8	36.7	46.7
BC (%)					15.1	16.9	19.7	20.8

RCS, Range condition score; RC, range condition; BC, basal cover.

Ngubhela yielded poor range condition (35.4 and 36.7%, respectively). In the rehabilitated sites, the range condition indices increased to 41.8 and 46.7% respectively. A high relative abundance of increaser II and increaser III species (indication of overgrazing) was recorded in the degraded sites.

Basal cover

The basal cover ranged from low (15.1%) in degraded sites to high (20.8%) in the rehabilitated sites (Table 1). In the degraded sites of Mpameni and Ngubhela the basal cover could be characterised as low (16.9 and 15.1% respectively). The average distance between the point of the spike and the nearest grass tuft was 2.21 cm, while the average diameter of the tufts was 2.76 cm. In the rehabilitated sites, the Mpameni and Ngubhela degraded sites yielded a high basal cover of 19.7 and 20.8% respectively. The average distance between the point of the spike and the nearest grass tuft (D) was 1.67 cm, while the diameter of the tufts (d) was 4.58 cm. Basal cover at the Ngubhela sites increased by 5.7%, while it increased by 2.8% at the Mpameni sites (Figure 2).

Species diversity in response to rangeland degradation

Species diversity using Shannon's index was higher (2.92 and 3.12) in the rehabilitated sites when compared with the degraded sites (2.41 and 2.49) (Table 2). The results from a t-test indicated that there was a statistically significant difference between the Ngubhela rehabilitated and the Ngubhela degraded sites ($t = 9.194$, $P < 0.05$) as well as between the Mpameni rehabilitated and the Mpameni degraded sites ($t = 9.91$, $P < 0.05$).

Soil fertility properties

The results of the one-way ANOVA indicated that there was a significant difference ($P < 0.05$) in the soil properties (P, K, pH, OC and N) between the rehabilitated and degraded sites (Table 3). Among these, P, OC and N were highly significant (< 0.001). However, there were no significant differences ($P > 0.05$) between these sites for Ca, Mg, Zn, Mn, and Cu. The Ngubhela rehabilitated site had the highest mean values of P and OC (11.3 and 6.33%) respectively) among the study sites. The Mg was less than1.05 cmol/kg in the rehabilitated sites. However, it was greater than1.22 cmol/kg in the degraded sites.

DISCUSSION

Changes in range condition

The range condition assessment successfully indicated a distinct difference in species composition between degraded and rehabilitated environments (Table 1). In the Mpameni and Ngubhela degraded sites, the range condition was classified as poor (35.4 and 36.7%). This can be

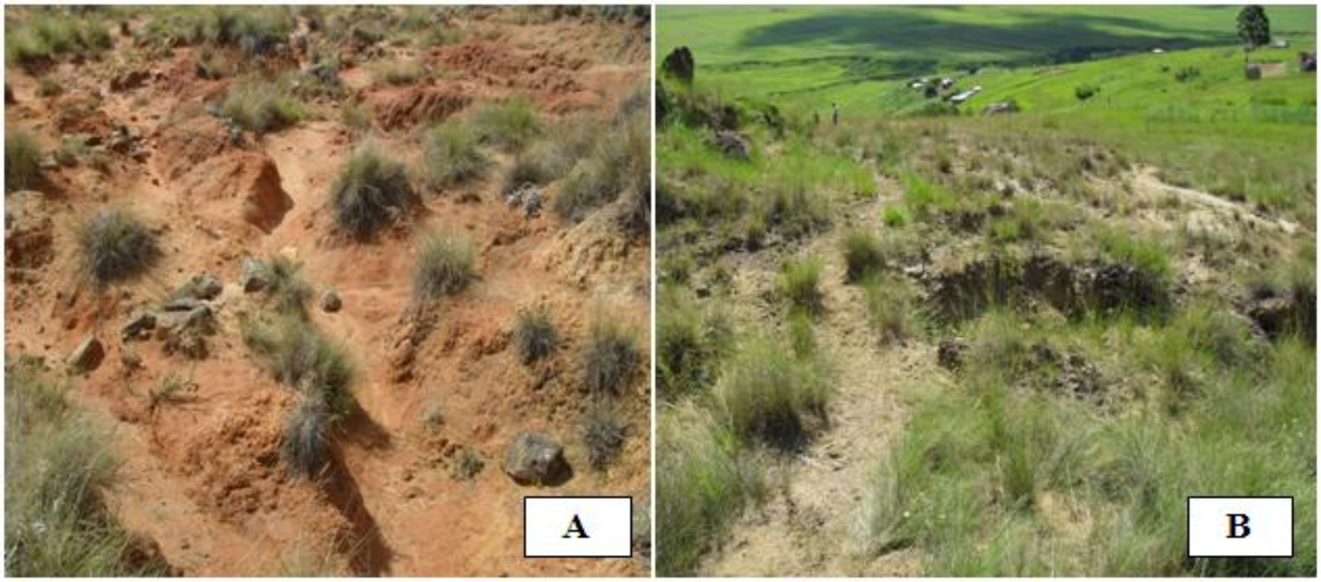

Figure 2. Constrast between degraded (A) and rehabilitated (B) sites at the Mpameni degraded site.

Table 2. Shannon's diversity index (H') for rehabilitated and degraded sites.

No.	Site	Shannon's diversity index (H')
1	Ngubhela rehabilitated	3.12
2	Mpameni rehabilitated	2.92
3	Ngubhela degraded	2.49
4	Mpameni degraded	2.41

explained by the fact that these sites were dominated by species such as *E. racemosa, Melinis repens*, and *A. diffusa*. These grasses are unpalatable and thus have low grazing value ranging from 0 to 6 according to the Moist Highland Sourveld benchmark (Camp, 1997; Van der Westhuizen et al., 2005; Van Oudtshoorn, 1992). The dominance of these species may be attributable to low soil organic carbon (< 2.10%) and nitrogen (< 0.16%) (Table 2). Range condition degraded sites increased from 35.4 and 36.7 to 41.8 and 46.7% after rehabilitation. Both the rehabilitated and degraded sites had few palatable species (0 - 1%) when compared with the benchmark (49%). This indicates a loss in grazing quality of the rangeland. The rehabilitated and degraded sites had a high abundance of *M. repens* (characteristic of disturbed areas) and *A. diffusa* (a species associated with shallow soils in overgrazed rangeland). These species were absent in the benchmark, and their dominance indicates poor rangeland condition (Camp, 1997). The rehabilitated sites had an average range condition when compared with the degraded areas. This may be attributable to the success of the rehabilitation techniques used by the community in the PES project which was established in communal rangelands to promote ecologically sustainable approaches to rangeland management (Everson et al., 2007).

Changes in basal cover

Basal cover at the Mpameni and Ngubhela rehabilitated sites increased by 2.8 to 5.7% following fencing and rehabilitation of the site. Rehabilitation techniques were employed that involved building stone packs and structures inside the gullies and any steep slopes in order to retain silt and sediments. Plants which are effective for covering bare land and protect soil from wind and water erosion were planted in sensitive places: Vetiveria grass (*Vetiveria zizanoides*), Kikuyu grass (*Pennisetum clandestinum*), and indigenous trees (*Acacia karroo*). Everson et al. (2007) noticed that run-off water decreases in rehabilitated sites. The rain splash height in the Mpameni degraded site was 2.30 mm higher than the 1.62 mm for the rehabilitated site (Everson et al., 2007). This is attributable to lower basal cover which is influenced by grazing management, and which in turn influences the stream flow response. By contrast, basal cover decreased in the degraded sites of Ngubhela and

Table 3. The mean, standard deviation, and P values of the soil properties for the rehabilitated (Mpameni and Ngubhela) and degraded (Mpameni and Ngubhela) sites.

Soil properties	Rehabilitated	Degraded	P value	Rehabilitated	Degraded	P value
	Ng	Ng		Mg	Mg	
P (mg/kg)	11.36 ± 3.62 (5.88 - 22.50)	4.49 ± 1.99 (2.61 - 10.10)	0.001**	9.06 ± 1.73 (5.65 - 12.74)	4.91 ± 1.90 (2.54 - 9.73)	0.001**
K (cmol/kg)	0.47 ± 0.17 (0.05 - 0.91)	0.37 ± 0.24 (0.05 - 1.05)	0.036*	0.30 ± 0.17 (0.05 - 0.91)	0.33 ± 0.23 (0.15 - 1.05)	0.048*
Ca (cmol/kg)	3.41 ± 1.31 (0.25 - 5.53)	2.12 ± 1.88 (0.24 - 6.67)	0.060^{ns}	3.43 ± 1.28 (0.25 - 5.53)	3.26 ± 2.35 (0.61 - 8.67)	0.763^{ns}
Mg (cmol/kg)	1.05 ± 0.37 (0.08 - 1.93)	1.22 ± 1.20 (0.04 - 4.35)	0.310^{ns}	1.04 ± 0.35 (0.08 - 1.93)	1.52 ± 1.00 (0.32 - 3.71)	0.054^{ns}
pH_{KCl}	4.11 ± 0.27 (3.10 - 4.54)	3.85 ± 0.66 (1.2 - 4.84)	0.047*	4.20 ± 0.21 (3.80 - 4.84)	3.90 ± 0.44 (3.09 - 4.90)	0.039 *
Zn (cmol/kg)	0.50 ± 0.25 (0.10 - 1.12)	0.78 ± 0.56 (0.17 - 2.38)	0.052^{ns}	0.87 ± 0.569 (0.10 - 1.83)	1.15 ± 0.87 (0.10 - 3.69)	0.262^{ns}
Mn (cmol/kg)	6.24 ± 1.63 (2.02 - 8.22)	5.40 ± 3.60 (2.54 - 21.21)	0.057^{ns}	7.69 ± 4.08 (2.02 - 15.00)	6.56 ± 2.02 (3.88 - 9.48)	0.219^{ns}
Cu (cmol/kg)	2.01 ± 0.62 (0.01 - 2.55)	1.56 ± 1.38 (0.01 - 4.78)	0.136^{ns}	2.07 ± 0.52 (0.01 - 2.63)	3.32 ± 4.00 (0.01 - 4.78)	0.856^{ns}
OC (%)	6.33 ± 0.89 (5.40 - 8.90)	2.00 ± 0.87 (0.8 - 4.50)	0.001**	5.65 ± 1.68 (0.80 - 8.20)	2.10 ± 1.47 (0.80 - 4.50)	0.001**
N (%)	0.55 ± 0.15 (0.32 - 0.86)	0.12 ± 0.07 (0.05-0.32)	0.001**	0.70 ± 0.23 (0.05 - 0.99)	0.16 ± 0.08 (0.05 - 0.32)	0.001**

Ng, Ngubhela; Mg, Mpameni; *, significant P value; **, highly significant P value; ns, non-significant P value. Values between brackets are the minimum and maximum values.

Mpameni (poor range condition). Tessema et al., (2011) point out that basal cover decreases as a result of heavy grazing. The basal cover of the Ngubhela degraded site was higher (16.9%) than that of the Mpameni site (15.1%) which is attributable to the dense nature of increaser II tufts as well as the larger number of stoloniferous grasses such as the Paspalum species.

Variations in species diversity in response to rangeland degradation

There were differences in the Shannon diversity index between the rehabilitated and degraded sites (Table 2). Changes in soil properties could be responsible for the variation in species diversity (Stohlgren et al., 1999). Soil analysis showed a decline in soil properties such as P 2.54 mg/kg, OC 2.10% and N 0.16%. These properties are considered important in plant growth and survival (Oluwole and Dube, 2008). In the degraded sites (Mpameni and Ngubhela), the species diversity index was moderate at 2.41 and 2.49 respectively. These results are similar to those obtained in previous studies of degraded grasslands (Anderson and Hoffman, 2007; Stohlgren et al., 1999; Todd and Hoffman, 1999), indicating that overgrazing on communal rangeland results in a decreased proportion of palatable grass species as well as in an increased proportion of unpalatable grass species. The results of this study indicate that the rehabilitated sites of Mpameni and Ngubhela have a higher diversity index of 2.92 and 3.12 compared with the degraded sites. The higher diversity index recorded in the Ngubhela rehabilitated site (3.12) isattributable to the fact that it has experienced long-term rehabilitation. The rehabilitated sites were dominated by different species, namely *E. racemosa*, *E. curvula*, *E. plana*, *P. clandestinum*, *H. hirta*, *S. africanus*, *V. zizanoides*, *Paspalum dilatatum* and *P. notatum*. This state of affairs may be due to the planting in the rehabilitated sites of different species such as *P. clandestinum*, *V. zizanoides*, and indigenous and exotic grasses (Everson et al., 2007; Peden, 2005). Moreover, there are certain environmental management programmes in place to ensure that the rehabilitated sites are protected from harmful human activities.

Changes in soil fertility properties as an indicator of rangeland degradation

The results of this study indicate that there were significant differences ($P < 0.05$) in soil properties (P, K, pH, OC and N) between the degraded and rehabilitated sites (Table 3). P, K, pH, OC and N were generally higher at the rehabilitated sites as compared with the degraded sites. This may be owing to the rehabilitation programme that focused on reducing soil erosion and run-off in the rehabilitated sites. These results are comparable to the results of previous studies (Islam and Weil, 2000; Oluwole and Dube, 2008) which also indicate that the overgrazing of rangelands has a negative impact on vegetation species and soil properties because of reduced vegetation cover, reduced productivity, and litter accumulation. These factors reduce soil infiltration, enhance soil erosion vulnerability, and lead to a decline in soil fertility. By contrast, the average range condition as measured in the rehabilitated sites (41.8 and 46.7%) indicated good soil fertility (increase of OC and total N). The high values of OC and N in vegetation growth are considered the main causes behind high vegetation diversity in the rehabilitated sites (Du Preez and Snyman, 1993; Oluwole and Dube, 2008).

Conversely, the decrease in species diversity in the degraded sites may be linked with poor soil fertility (low OC 2.10% and N 0.16%). Low OC and total N are caused by vital nutrients being leached from the soil as the result of heavy rainfall; this range type generally occurs in acid soil which is poor in nutrients (Tainton, 1999). A higher pH (4.11 and 4.20) in the rehabilitated sites indicated their improved soil nutrient status when compared with the pH of the degraded sites (3.85 and 3.90).

Conclusion

Management of natural resources is important to prevent and reduce rangeland degradation. Rangeland rehabilitation programmes using payment of environmental services (PES) have the potential to promote effective management of rangeland through different activities such as planting perennial trees and grasses and implementing a rotational grazing system to reduce soil erosion and run-off, as well as an increase in vegetation basal cover and grass production. The loss of P 2.54 mg/kg, OC 2.10% and N 0.16% are an indication of the degradation of soil quality and decline in productivity of rangeland. Overall, the study has demonstrated the potential of different indicators (that is, range condition, basal cover, species diversity, and soil properties) for evaluating rangeland degradation. In this regard, we expect that the results of the study can be used to support up-to-date monitoring systems for sustainable rangeland management. Further research to quantify the effect of grazing management systems in communal rangelands on water resources is therefore recommended together with a community-based monitoring system to improve the environmental awareness of the community for understanding the relationship between livestock grazing management and hydrological benefits.

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REFERENCES

Anderson P, Hoffman M (2007). The impacts of sustained heavy grazing on plant diversity and composition in lowland and upland habitats across the Kamiesberg mountain range in the Succulent Karoo, South Africa. J. Arid Environ. 70(4):686-700.

Barnes D, Rethman N, Beukes B, Kotze G (2007). Veld composition in relation to grazing capacity. Afr. J. Range. Forage Sci. 1(1):16-19.

Beisel JN, Moreteau JC (1997). A simple formula for calculating the lower limit of Shannon's diversity index. Ecol. Modell. 99(2-3):289-292.

Bosch O, Gauch H (1991). The use of degradation gradients for the assessment and ecological interpretation of range condition. J. Grassland Soc. Southern Afr. 8(4):138-146.

Camp K (1997). The bioresource groups of KwaZulu-Natal. Cedara Report.

Chao A, Shen TJ (2003). Nonparametric estimation of Shannon's index of diversity when there are unseen species in sample. Environ. Ecol. 10(4):429-443.

Dollar E, Goudy A (1999). Environmental change. In: Fox R, Rowntree K (eds), The geography of South Africa in a changing world. Oxford University Press, Oxford. P. 477.

Du Preez C, Snyman H (1993). Research note: Organic matter content of a soil in a semi-arid climate with three long-standing veld conditions. Afr. J. Range Forage Sci. 10(2):108-110.

Everson TM, Everson CS, Zuma KD (2007). Community based research on the influence of rehabilitation techniques on the management of degraded catchments. WRC Report 1316/1/07 97:1-97.

Foran B, Tainton N, Booysen P (1978). The development of a method for assessing veld condition in three grassveld types in Natal. Proc. Ann. Congr. Grassland Soc. South. Afr. 13(1):27-33.

Hardy M, Tainton N (2007). Towards a technique for determining basal cover in tufted grasslands. Afr. J. Range. Forage. Sci. 10(2):77-81.

Hardy MB, Hurt CR, Bosch OJH (1999). Grassveld. In: Tainton NM (ed), Veld management in South Africa. University of Natal Press, Pietermaritzburg. pp. 195-206.

Hoffman M, Todd S (2000). A national review of land degradation in South Africa: the influence of biophysical and socio-economic factors. J. Southern Afr. Stud. 26(4):743-758.

Hurt CR, Hardy MB (1989). A weighted key species method for monitoring changes in species composition of Highland Sourveld. Afr. J. Rang. Forage Sci. 6(3):109-113.

Islam K, Weil R (2000). Land use effects on soil quality in a tropical forest ecosystem of Bangladesh. Agric.Ecosyst. Environ. 79(1):9-16.

Jordaan F, Biel L, Du Plessis P (1997). A comparison of five range condition assessment techniques used in the semi-arid western grassland biome of southern. Afr. J. Arid Environ. 35(4):665-671.

Lande R (1996). Statistics and partitioning of species diversity, and similarity among multiple communities. Oikos 76(1):5-13.

Mansour K, Mutanga O, Everson T, Adam E (2012). Discriminating indicator grass species for rangeland degradation assessment using hyperspectral data resampled to AISA Eagle resolution. ISPRS J. Photogramm. Remote Sens. 70:56-65.

Mapiye C, Mwale M, Chikumba N, Chimonyo M (2008). Fire as a rangeland management tool in the savannas of Southern Africa: A review. Trop. Subtrop. Agroecosys. 8(2):115-124.

Mentis M (1981). Evaluation of the wheel-point and step-point methods of veld condition assessment. Afr. Range. Forage. Sci. 16(1):89-94.

Metzger K, Coughenour M, Reich R, Boone R (2005). Effects of seasonal grazing on plant species diversity and vegetation structure in a semi-arid ecosystem. J. Arid Environ. 61(1):147-160.

McCarty GW, Reeves J, Yost R, Doraiswamy PC, Doumbia M (2010). Evaluation of methods for measuring soil organic carbon in West African soils. Afr. J. Agric. Res. 5(16):2169-2177.

Mucina L, Rutherford M (2006). The vegetation of South Africa, Lesotho

and Swaziland–Strelitzia 19, South African National Biodiversity Institute, Pretoria. P. 807.
Oluwole FA, Dube S (2008). Land degradation evaluation in a game reserve in Eastern Cape of South Africa: Soil properties and vegetation cover. Sci. Res. Essays 3(3):111-119.
Passmore G, Brown CG (1991). Analysis of rangeland degradation using stochastic dynamic programming. Aust. J. Agric. Econ. 35(2):131-157.
Payne RW, Harding SA, Murray DA. Soutar DM, Baird DB, Glaser AI, Channing IC, Welham SJ, Gilmour AR, Thompson R, Webster R (2009). The Guide to GenStat® Release 12, Part 2: Statistics. VSN International, Hemel Hempstead, United Kingdom, P. 13.
Peden M (2005). Tackling'the most avoided issue: communal rangeland management in KwaZulu-Natal, South Africa. Afr. J. Range. Forage. Sci. 22(3):167-175.
Rutherford M, Powrie L (2010). Severely degraded rangeland: Implications for plant diversity from a case study in Succulent Karoo. South Afr. J. Arid Environ. 74(6):692-701.
Shackleton CM (2000). Comparison of plant diversity in protected and communal lands in the Bushbuckridge lowveld savanna. South Africa. Biological Conserv. 94(3):273-285.
Shannon CE, Weaver W (1963). The mathematical theory of communication. University of Illinois Press, Urbana.
Snyman H (1998). Dynamics and sustainable utilization of rangeland ecosystems in arid and semi-arid climates of southern African. J. Arid. Environ. 39(4):645-666.
Snyman H (2003). Revegetation of bare patches in a semi-arid rangeland of South Africa: an evaluation of various techniques. J.Arid.Environ. 55(3): 417-432.
Snyman H, Du Preez C (2005). Rangeland degradation in a semi-arid South Africa--II: influence on soil quality. J. Arid Environ. 60(3):483-507.
Stohlgren TJ, Schell LD, Vanden Heuvel B (1999). How grazing and soil quality affect native and exotic plant diversity in Rocky Mountain grasslands. Ecol. Appl. 9(1):45-64.
Tainton N, Edwards P, Mentis M (1980). A revised method for assessing veld condition. Proc. Annu. Congr. Grassland Soc. Southern Afr. 15(1):37-42.
Tainton NM (1999). The grassland biome. In: Tainton, NM (ed), Veld management in South Africa. University of Natal Press, Pietermaritzburg. pp. 25-33.
Temme A (2008). Understanding landscape dynamics over thousand years: combining field and model work: with case study in the Drakensberg foothill, KwaZulu-Natal, South Africa. In, School of Environmental Sciences. Pietermaritzburg, South Africa, University of KwaZulu-Natal.
Tessema ZK, de Boer WF, Baars RMT, Prins HHT (2011). Changes in soil nutrients, vegetation structure and herbaceous biomass in response to grazing in a semi-arid savanna of Ethiopia. J. Arid. Environ. 75(7):662-670.
The Non-Affiliated Soil Analysis Work Committee (1990). Handbook of standard soil testing methods for advisory purposes. Soil Sci. Soc. of South Afr. Pretoria. P. 160.
Todd S, Hoffman M (1999). A fence-line contrast reveals effects of heavy grazing on plant diversity and community composition in Namaqualand, South Africa. Plant Ecol. 142(1):169-178.
Trollope W (1990). Development of a technique for assessing veld condition in the Kruger National Park using key grass species. J. Grassland. Soc. South. Afr. 7(1):46-51.
Trollope W (2011). Personal perspectives on commercial versus communal Afri-can fire paradigms when using fire to manage rangelands for domestic livestock and wildlife in southern and east African ecosystems. Fire Ecol. 7(1):57-73.
UNCCD (1995). United Nations Convention to Combat Desertification in Countries Experiencing Serious Drought and/or Desertification, Particularly in Africa, text with Annexes. UNEP, Geneva, Switzerland.
Van der Westhuizen H, Snyman H, Fouché H (2005). A degradation gradient for the assessment of rangeland condition of a semi-arid sourveld in southern Africa. Afr. J. Range. Forage Sci. 22(1):47-58.
Van Oudtshoorn FP (1992). Guide to grasses of South Africa. Briza Publications, Pretoria, South Africa. pp. 125-163.
Von Maltitz GP (1998). Communal rangeland management options for the Okhombe community. In: de Bruyn TD, Scogings PF (eds), Communal rangelands in southern Africa: a synthesis of knowledge, Proceedings of a symposium on policy-making for the sustainable use of southern Africa communal rangelands, University of Fort Hare, South Africa. P. 68.
Vorster M (1982). The development of the ecological index method for assessing veld condition in the Karoo. Proc. Annu. Congr. Grassland Soc. South. Afr. 17(1):84-89.
Wessels K, Prince S, Frost P, Van Zyl D (2004). Assessing the effects of human-induced land degradation in the former homelands of northern South Africa with a 1 km AVHRR NDVI time-series. Remote Sens. Environ. 91(1):47-67.
Wu R, Tiessen H (2002). Effect of land use on soil degradation in alpine grassland soil, China. Soil Sci. Soc. Am. J. 66(5):1648-1655.