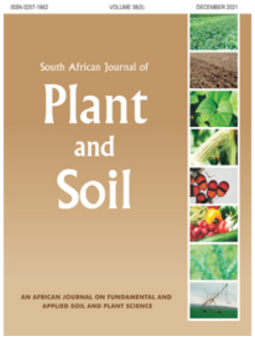

South African Journal of Plant and Soil

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/tjps20

Effect of soil type on spatial distribution and nutritive value of grass species growing in selected rangelands of South Africa

Khuliso E Ravhuhali, Victor Mlambo, Tefera S Beyene & Lobina G Palamuleni

To cite this article: Khuliso E Ravhuhali, Victor Mlambo, Tefera S Beyene & Lobina G Palamuleni (2021) Effect of soil type on spatial distribution and nutritive value of grass species growing in selected rangelands of South Africa, South African Journal of Plant and Soil, 38:5, 361-371, DOI: 10.1080/02571862.2021.1933630

To link to this article: https://doi.org/10.1080/02571862.2021.1933630

South African Journal of Plant and Soil 2021, 38(5): 361–371
Printed in South Africa — All rights reserved

© Southern African Plant & Soil Sciences Committee
SOUTH AFRICAN JOURNAL OF PLANT AND SOIL
ISSN 0257-1862 EISSN 2167-034X
https://doi.org/10.1080/02571862.2021.1933630

Effect of soil type on spatial distribution and nutritive value of grass species growing in selected rangelands of South Africa

Khuliso E Ravhuhali[1,2]*, Victor Mlambo[3], Tefera S Beyene[4] and Lobina G Palamuleni[5]

[1] Department of Animal Science, School of Agricultural Sciences, Faculty of Natural and Agricultural Sciences, North-West University, Mmabatho, South Africa.
[2] Food Security and Safety Niche Area, School of Agricultural Sciences, Faculty of Natural and Agricultural Sciences, North-West University, Mmabatho, South Africa.
[3] School of Agriculture, Faculty of Agriculture and Natural Sciences, University of Mpumalanga, Mbombela, South Africa.
[4] Department of Livestock and Pasture Science, University of Fort Hare, Alice, Eastern Cape, South Africa
[5] Department of Geography and Environmental Sciences, School of Geo and Spatial Sciences, Faculty of Natural and Agricultural Sciences, North-West University, Mmabatho, South Africa.
** Correspondence: khuliso.ravhuhali@nwu.ac.za*

The distribution and status of grass species is essential for sustainable management of rangelands. Therefore, this study assessed the spatial distribution and nutritive value of grass species as influenced by soil type in selected rangelands of the North West province of South Africa. Grass species were harvested from four communal areas (clay loam and red brown sand soil types) using three transects per study area. Each transect was sub-divided into near (0.5–0.7 km), middle (0.70–1.4 km) and far sub-transects (1.4–2.2 km) based on distance from homesteads. Within each sub-transect, 10 m × 10 m homogeneous vegetation units (HVU) were marked and quadrats (1 m^2) were randomly placed within each HVU to sample soil and grasses. Species composition, abundance, biomass and nutritive value of grass species were measured. Only 21% of grasses identified in the study areas were determined to be of high grazing value. *Aristida* species were more common and dominant in both soil types. *Eragrostis cylindriflora 2* Hochst. had higher crude protein content and the highest *in vitro* ruminal dry matter degradability after 24 and 48 hours. Thus, *E. cylindriflora* was the most valuable grass species for livestock farming in the study areas and could be earmarked for rangeland restoration.

Keywords: biomass, communal areas, semi-arid, soil minerals, vegetation management

Introduction

Grasses are the major feed resource for ruminants in some semi-arid rangelands (Ahamefule et al. 2006). The abundance of grass species in semi-arid communal areas is influenced by several factors, such as climatic conditions, soil fertility and grazing pressure. Indeed, the interaction between grazing pressure and climatic conditions alters grass species diversity (Pulungan et al. 2019; Rahmanian et al. 2019). High grazing pressures and poor climatic conditions that prevail in semi-arid communal rangelands may result in an undesirable and often irreversible shift from perennial (climax/subclimax) to annual (pioneer) grass species (Škornik et al. 2010). This is an example of how unsustainable rangeland management practices can be exacerbated by low rainfall and increases in temperature associated with climate change (Polley et al. 2017).

Climate change has been proposed as a cause of strong seasonality in grassland production in semi-arid areas (Dangal et al. 2016; Miranda et al. 2011) such as in the North West province of South Africa. Severe droughts and heavy rains are equally likely to occur in these areas, resulting in wind or water erosion and hence severe losses in soil, grass biomass yields (Hannusch et al. 2020) and grass nutritive value (Bista et al. 2018). High temperatures also affect soil water by accelerating evapotranspiration, increasing the size of soil cracks and increasing the frequency of their formation (Várallyay 2010).

The nutritive value of different grass species has been studied widely, but there are many factors that cause variations in this parameter. The most important of these factors are growing conditions that are influenced by climate, soil type, water and nutrient availability, all of which are influenced by a geographical location (Särkijärvi et al. 2012). There is also evidence that plant community structure affects the composition of soil communities (Grayston et al. 2004; Fraterrigo et al. 2005). Hufford et al. (2014) stated that the relationship between plant species distribution and soil properties may provide a means to determine suitable species for rangeland restoration. Grass species distribution reflects spatial processes as well as adaptation to heterogeneous environments (Kramer et al. 2011). Soininen and Hillebrand 2007 demonstrated that species with limited dispersal tend to show strong relationships with edaphic characteristics, and their distribution declines rapidly towards watering points and homesteads. Assessment of the distribution, status and nutritive value of native grass vegetation is thus essential for sustainable management of this ecological system given that some grass species are more susceptible to grazing than others. It is important to identify the most dominant grass species in communal rangelands and determine their potential feed value for grazing livestock.

Little is known about the spatial distribution and nutritive value of grass species in relation to soil characteristics and distance towards homesteads in the communal grazing lands of the North West province in South Africa. This study, therefore, assessed the spatial distribution, chemical composition and *in vitro* ruminal fermentation of some grass species as influenced by soil type and distance from homesteads in selected communal grazing lands of the North West province.

Material and methods

Ethical approval for this study was obtained from North-West University Animal Research Ethics Committee, Approval number NWU-00126-13-A9. The cannulated animal was cared for according to the guidelines provided by North-West University and the Federation of Animal Science Societies (FASS 2010).

Study areas

The study was conducted in four communal rangeland sites in the Ngaka Modiri Molema district of the North West province, South Africa. The selected rangelands were Tsetse, Six-hundred, Makgobistadt and Leporong (Table 1).

The Tsetse and Six-hundred rangelands are located next to each other and are dominated by a Dry Highveld Grassland vegetation type (Mucina and Rutherford 2006). These two rangelands are 50 km from the other two rangelands, namely Makgobistadt and Leporong, which are also located next to each other, but with a vegetation cover of Eastern Kalahari Bushveld (Mucina and Rutherford 2006). The four rangelands were selected, as they are highly overgrazed and spanned two different soil types. All the rangelands received 400–450 mm of rainfall per annum, while ambient temperatures varied from 02–36 ºC throughout the year. The types of livestock that make use of rangelands in the study areas are cattle, goats, sheep and donkeys (Ravhuhali et al. 2020a). Soil type, altitude and the coordinates of the selected sampling sites in the communal areas are presented in Table 1.

Table 1: Soil type, altitude, coordinates and carrying capacity of the selected sampling sites

Communal site	Distance	Soil type	Altitude (m)	Coordinates	Ha/Large Stock Unit
Tsetse	Near	CL[a]	1308	25°44.284 S 25°41.008 E	13
	Middle	CL	1302	25°44.776 S 25°40.533 E	10.6
	Far	CL	1309	25°45.120 S 25°40.490 E	9.7
Six-hundred	Near	CL	1287	25°43.427 S 25°38.170 E	14.4
	Middle	CL	1296	25°43.133 S 25°38.597 E	8.8
	Far	CL	1299	25°42.755 S 25°39.017 E	8.0
Makgobistadt	Near	RBS[b]	1160	25°45.687 S 25°05.232 E	32.7
	Middle	RBS	1177	25°46.198 S 25°04.822 E	26.1
	Far	RBS	1182	25°46.642 S 25°04.141 E	22.2
Leporong	Near	RBS	1117	25°45.957 S 25°58.872 E	22.2
	Middle	RBS	1148	25°46.909 S 24°59.035 E	18.9
	Far	RBS	1165	25°47.829 S 24°59.597 E	16.0

[a] CL = clay loam

[b] RBS = red brown sand

Sampling and chemical analyses of grass and soil

Soil samples were collected from each of the nine sub-transects per grazing area. The samples were collected at a depth of 200 mm using auger equipment. They were air-dried and sieved through a two-millimetre mesh screen prior to analysis using an ICP machine for phosphorus (P) (Olsen and Sommers 1982), nitrogen (N) (van Reeuwijk 1992), organic carbon (OC) (Baker 1976), potassium (K), calcium (Ca), magnesium (Mg), sodium (Na), iron (Fe), zinc (Zn), copper (Cu), and manganese (Mn) (Jackson 1970). The soils were also analysed for pH (H_2O) using a pH meter. Soil texture was determined by using the hydrometer method as described by Ashworth et al. (2001).

Three transects 2.2 km long and 200 m apart, were established in each rangeland radiating away from homesteads. Each transect was sub-divided into near (0.5–0.7 km), middle (0.70–1.4 km) and far sections (1.4–2.2 km), based on distance from homesteads, thus producing nine sampling sub-transects per study site. The length of each sub-transect was based on the average size of selected grazing areas and the species diversity in the selected study sites. Three 10 m × 10 m homogeneous vegetation units (HVUs) were marked out in each sub-transect, 20 m apart, resulting in a total of 27 HVUs per grazing area. In each HVU, one quadrat (1 m^2) was randomly placed **to** sample grass species and soil. After identification and classification, grasses within each quadrat were harvested (5 cm from the surface) for biomass determination before being dried and milled through a 1 mm sieve in preparation for chemical analyses and *in vitro* ruminal fermentation. Grass species were grouped according to their grazing value (acceptability; van Oudtshoorn 2014), ecological form (decreaser/increaser i/increaser ii/increaser iii/invaders species), life forms (annual or perennial species) and abundance (dominant or common, rare, present). Dominant grass species are those whose average frequency in a site exceeded 13%, while those whose frequency ranged from 3% to 13% were classified as common (Tefera et al. 2010). Milled grass samples were analysed for DM by drying at 100 °C in an oven for 12 hours, while OM was determined according to AOAC (2012, method no. 973.18). Total N was determined using the macro-Kjeldahl method (AOAC 2012, method no. 976.06), while crude protein was obtained by multiplying the N value with a factor of 6.25. Neutral detergent fibre (NDF) and acid detergent fibre (ADF) were determined by refluxing samples (0.45 g) with NDF and ADF solutions, respectively, for an hour using an ANKOM^{2000} fibre analyser (ANKOM Technology, Macedon, New York). Acid detergent lignin (ADL) was determined by difference after dissolving cellulose from ADF residue using 72% H_2SO_4 (Van Soest et al. 1991).

In vitro ruminal fermentation of grasses

In vitro ruminal dry matter degradability (DMD) of grasses was determined using an ANKOM Daisy^{II} incubator (ANKOM Technology Corp Fairport, NY) with four rotating jars. The rumen fluid donor was a fistulated Bonsmara cow fed a conditioning diet containing buffalo grass (*Cenchrus ciliaris L.*) and lucerne. About half a gram of grass samples were weighed into ANKOM F57 bags, which were subsequently heat-sealed. Samples for zero hours were then soaked in warm water (39 °C) for 20 minutes and dried at 105 °C. The other ANKOM bags were placed into jars containing rumen fluid and an ANKOM buffer followed by purging using CO_2 to ensure an anaerobic environment, before tightly closing the jars. The samples were incubated at 39 °C with constant rotation. The ANKOM F57 bags were withdrawn at 24 hours and 48 hours after inoculation, washed with cold water for 20 minutes and dried at 105 °C to determine the dry matter degradability (DMD). The following formula was used to calculate DMD:

$$\%\mathrm{DMD} = \frac{100-(w_3-\left(w_1\times c_1\right)}{w_2\times \mathrm{DM}}\times 100 \qquad (1)$$

Where: w_1 = bag tare weight, w_2 = sample weight, w_3 = final weight after inoculation and c_1 = correctional factor.

Statistical analysis

The effect of soil type and distance from homesteads on soil chemical composition, species abundance and grass biomass yield data were analysed using the General Linear Model (GLM) procedures of SAS (2010) according to the following statistical model:

$$y_{ijk} = \mu + S_i + D_j + \left(S\times D\right)_{ij} + \varepsilon_{ijk} \qquad (2)$$

where μ = overall mean, S = effect of soil type, D = effect of distance from homesteads, (S×D) = interaction between soil type and distance from homesteads, while ε_{ijk} was the residual error.

The effect of distance from homesteads and grass species on chemical composition and *in vitro* ruminal degradability were analysed separately for each soil type, according to the following statistical model:

$$y_{ijk} = \mu + P_i + D_j + \left(PxD\right)_{ij} + \varepsilon_{ijk} \qquad (3)$$

where μ = overall mean, P = effect of plant species, D = effect of distance from homesteads, P×D) = interaction between plant species and distance from homesteads, with ε_{ijk} the residual error.

In both analyses, the probability of difference (pdiff) options in the least squares means statement were used to separate the means (SAS 2010). Statistically significant differences were declared at $p \leq 0.05$.

Results

Grass layer composition and distribution

Aristida congesta Roem. & Schult. and *Eragrostis pilosa* (L.) P.Beauv. were found to be dominant in all the sites. In CL soil, *Aristida adscensionis* L. and *Cymbopogon pospischilii* (K.Schum.) C.E.Hubb. grasses were classified as common, with their frequencies increasing with distance from the homesteads (Table 1). *A. congesta* dominated ($p < 0.05$) in RBS soil regardless of distance from homesteads. In CL soil, *Bothriochloa bladhii* (Retz.) S.T.Blake was classified as dominant near the homesteads, but the frequency declined to the common category with distance from the homestead in the middle and far sites. A total of 28 grass species were identified across all four study sites. Twenty of these species were classified as perennials. Of the total grass species found in the study areas, 21%, 50%, and 29% were classified as belonging to the high, medium, and low grazing value categories, respectively (Table 2).

Grass desirability and biomass production

The frequency of less desirable, desirable and highly desirable grass species has been presented in Table 3. In the CL soil, the frequency of less desirable grass species was not influenced by distance from the homesteads. Both soil types had the same proportions of grass species classified as belonging to low, medium and high grazing value groups. Within each soil type, all soil types had higher ($p < 0.05$) biomass production in the middle and far sites when compared to near homestead sites (Table 4). All distances on CL soil type had higher biomass production when compared to those distances under RBS soil type. There was a significant effect of soil type × distance interaction on the biomass production (kg/ha) on both soil types. Within each soil type, all soil types had higher ($p < 0.05$) biomass production in the middle and far sites when compared to near homestead sites (Table 4). All distances on CL soil type had higher biomass production when compared to those distances for the RBS soil type.

Soil nutrients

Distance and its interaction with soil type had no influence ($p > 0.05$) on soil N and pH. Soil type, distance and the soil type × distance interaction influenced soil OC content. The same factors also influenced ($p < 0.05$) soil macro and micro minerals, except for P (Figure 1). Clay loam soil had higher pH (H_2O) and N than RBS soil regardless of the distance from homesteads. Regardless of distance from the homesteads, CL soil had higher ($p < 0.05$) OC content than RBS soil. In near and middle sites, CL soil had a higher ($p < 0.05$) P concentration (3.5 ± 0.215 mg/kg and 4.00 ± 0.215 mg/kg, respectively) than RBS soil (2.5 ± 0.215 mg/kg and 2.5 ± 0.215 mg/kg). In CL soil, the Ca concentration was higher ($p < 0.05$) in the middle and near sites (377.5 ± 0.720 mg/kg and 375.0 ± 0.720 mg/kg, respectively) than in the far sites (286.6 ± 0.720 mg/kg). However, in the RBS

Table 2: Life form, palatability and abundance of grass species in the two soil types.

	Life form	Ecological status [a]	Grazing value [a]	Clay loam soil			Red brown sand		
				Near	Middle	Far	Near	Middle	Far
Aristida adscensionis L.	Ann	Inc ii	LGV	C	C	C	C	C	C
Aristida congesta Roem. & Schult.	Per/Ann	Inc ii	LGV	D	D	C	D	D	D
Aristida diffusa Trin.	Per/Ann	Inc ii	LGV	C	D	C	r	C	C
Aristida stipitata Hack.	Per/Ann	Inc ii	LGV	–	–	–	r	C	+
Centropodia glauca (Nees) Cope	Per	Dec	HGV	–	–	–	C	C	C
Chloris radiata (L.) Sw.	Ann	Inc ii	MGV	–	–	C	–	–	–
Cymbopogon pospischilii L. (K.Schum.) C.E.Hubb.	Per	Inc iii	LGV	C	C	C	–	–	–
Cynodon dactylon (L.) Pers.	Per	Inc ii	HGV	C	C	r	C	C	C
Bothriochloa bladhii (Retz.) S.T.Blake	Per	Inc ii	MGV	D	C	C	–	–	–
Digitaria eriantha Steud.	Per	Dec	HGV	–	r	r	–	r	r
Eragrostis cylindriflora 1 Hochst.[b]	Per	Inc ii	MGV	r	r	C	–	–	–
Eragrostis superba Peyr.	Per	Inc ii	MGV	r	r	+	–	–	–
Enneapogon cenchroides (Licht.) C.E.Hubb.	Per	Inc ii	MGV	+	+	+	–	+	+
Eragrostis pilosa (L.) P.Beauv.	Per	Inc ii	MGV	r	r	D	D	D	D
Eragrostis echinochloidea Stapf.	Per	Inc ii	MGV	C	r	r	–	r	r
Eragrostis cylindriflora 2 Hochst.[c]	Per	Inc ii	MGV	C	C	–			
Fingerhuthia africana Lehm.	Per	Dec	MGV	C	r	+	–	–	–
Heteropogon contortus Linnaeus, 1753	Per	Inc ii	MGV	r	+	–	–	–	–
Hyparrhenia filipendula (Hochst.) Stapf	Per	Inc i	MGV	–	+	–	–	–	–
Hyparrhenia hirta Linnaeus, 1753	Per	Inc i	MGV	r	–	–	–	–	–
Melinis repens (Willd.) Zizka	Per	Inc ii	LGV	–	r	+	–	r	+
Panicum maximum Jacq.	Per	Dec	HGV	C	r	+	–	–	–
Perotis patens Gand.	Ann	Inc ii	LGV	–	–	–	r	+	C
Setaria sphacelata (Schumach.) Stapf & C.E.Hubb. ex Moss	Per	Dec	MGV	+	–	–	–	–	–
Sporobolus fimbriatus (Nees ex Trin.) Nees	Per	Dec	HGV	r	–	–	–	–	–
Themeda triandra Forssk.	Per	Dec	HGV	–	C	C	–	–	–
Tragus berteronianus Schult.	Ann	Inc ii	LGV	–	–	–	r	+	r
Urochloa trichopus (Hochst.) Stapf	Per	Inc ii	MGV	–	+	C	–	–	r

[a] van Oudtshoorn 2014 [b] *Eragrostis cylindriflora* 1 Hochst. (*Eragrostis rigidior*) [c] *Eragrostis cylindriflora* 2 Hochst. (*Eragrostis trichopora*)

Ann = annual
Per = perennial
Inc i = Increaser i
Inc ii = Increaser ii
Inc iii = Increaser iii
Dec = decreaser
HGV = high grazing value
LGV = low grazing value
MGV = medium grazing value
D = dominant (> 13%)
r = rare (1–3%)
+ = present (< 1%)
C = common (> 3−13%)

Table 3: The effect of soil type and distance from homesteads on the frequencies (%) of desirability for groups of grass species

Distance	Grazing value					
	LGV		MGV		HGV	
	CL	RBS	CL	RBS	CL	RBS
Near (0.5–0.7 km)	10.1	9.49	6.53^{B}	39.45^{A}	1.8	5.76
Middle (0.7–1.4 km)	14.2	9.06	3.91^{B}	34.74^{A}	2.3	5.60
Far (1.4–2.1 km)	8.48	8.68	7.34^{B}	33.73^{A}	3.0	5.02
SE	2.55		8.25		0.73	

Within grazing value, means in the same row with different superscripts are significantly different ($p < 0.05$).

LGV = low grazing value
MGV = medium grazing value
HGV = high grazing value
CL = clay loam
RBS = red brown sand
SE = standard error

soil, Ca concentration declined with increasing distance from homesteads (Figure 2). RBS had the highest ($p < 0.05$) Fe (4.16 ± 0.014 mg/kg) concentration in the middle site than near (3.8 ± 0.014 mg/kg) and far sites (3.72 ± 0.014 mg/kg) (Figure 3). In CL soil, the Fe and Mn concentration increased with increasing distance from homesteads.

Chemical composition and in vitro ruminal fermentation of grasses

There was no spatial variation in terms of chemical composition of grass species in both CL and RBS soils (Tables 5 and 6). In CL soil, *Eragrostis trichopora* had the highest ($p < 0.05$) CP content compared to all other grass species

(Table 6). *Themenda triandra* Forssk. (34.8 g/kg DM)*, Aristida diffusa Trin.* (35.8 g/kg DM) and *Bothriochloa insculpta* (31.3 g/kg DM) had the lowest ($p < 0.05$) CP values. *Bothriochloa insculpta* had the highest ($p < 0.05$) ADL content (132.8 g/kg DM), while *Eragrostis echinochlodea* (63.9 g/kg DM) and *E. trichopora* (63.2 g/kg DM) had the lowest ($p < 0.05$) ADL values. In RBS soil, *Melinis repens (Willd.) Zizka* had the highest ($p < 0.05$) CP content (70 g/kg DM), while *E. echinochlodea* had the lowest CP value (36 g/kg DM) (Table 6). *Aristida congesta* had the same ($p > 0.05$) ADL content as *Cynodon dactylon (L.) Pers., A. diffusa, M. repens, Perotis patens Gand., Aristida stipitata Hack., Aristida adscensionis* and *Eragrostis pilosa* (L.) P.Beauv., while *Centropodia glauca* (Nees) Cope had the least ADL content. There was no spatial variation in terms of DMD of grasses in both CL and RBS soils (Tables 7, 8). The *in vitro* ruminal dry matter degradability of grasses growing in CL soil is presented in Table 7. *Cymbopogon pospischilii* (540.6 g/kg DM) and *E. trichopora* (562.0 g/kg DM) had the highest ($p < 0.05$) 48 h DMD values. In RBS soil, all grass species had similar 48 h DMD values (Table 8).

Table 4: Effect of soil type and distance from homesteads on biomass production (kg/ha) of the grass layer. In a row, different uppercase superscripts denote significant differences between soil type means ($p < 0.05$). In a column, different lowercase superscripts denote significant differences between distance means ($p < 0.05$)

Distance	Clay loam	Red brown sand
Near (0.5–0.7 km)	562.4^{bA}	231.7^{bB}
Middle (0.7–1.4 km)	1488.8^{aA}	698.0^{aB}
Far (1.4–2.2 km)	1570.5^{aA}	813.3^{aB}

Discussion

Soil properties

Insights into relationships between soil properties, among other abiotic factors, and grass species distribution, abundance and nutritive value are vital for the formulation of integrated solutions to land degradation in most communal areas (Tefera et al. 2005; Ravhuhali et al. 2020b). Therefore, exploratory studies are required to generate insights that are useful to farmers and rangeland scientists. Despite the obvious importance of rangelands as a primary feed resource for many herbivores in the communal areas of South Africa, very little information on the influence of soil type and grazing pressure on the distribution, abundance and nutritive value of the herbaceous layer is available. It is for this reason that this study was designed to explore the variation in grass species distribution and nutritive value in response to two different soil types and grazing pressure (distance from homesteads where animals are kept in enclosures overnight). Indeed, Britz (2004) reported that vegetation structure is normally

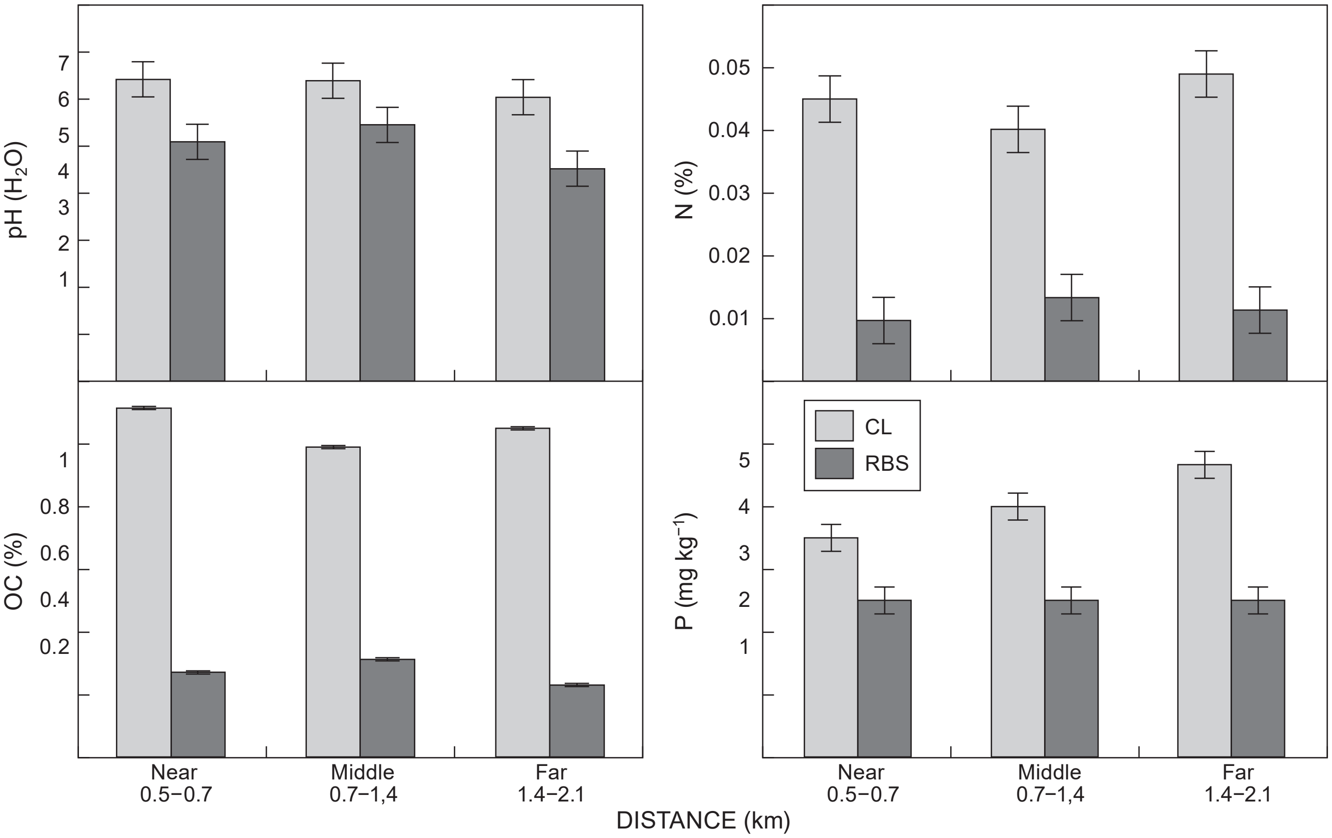

Figure 1: Influence of soil type (clay loam (CL) and red brown sand (RBS)) and distance (Near = 0.5–0.7 km; Middle = 0.7–1.4 km; Far = 1.4–2.1 km) from homesteads on pH, nitrogen (N), organic carbon (OC) and phosphorus (P) content of soil. Error bars: pH = 0.374; N = 0.004; OC = 0.005; P = 0.215.

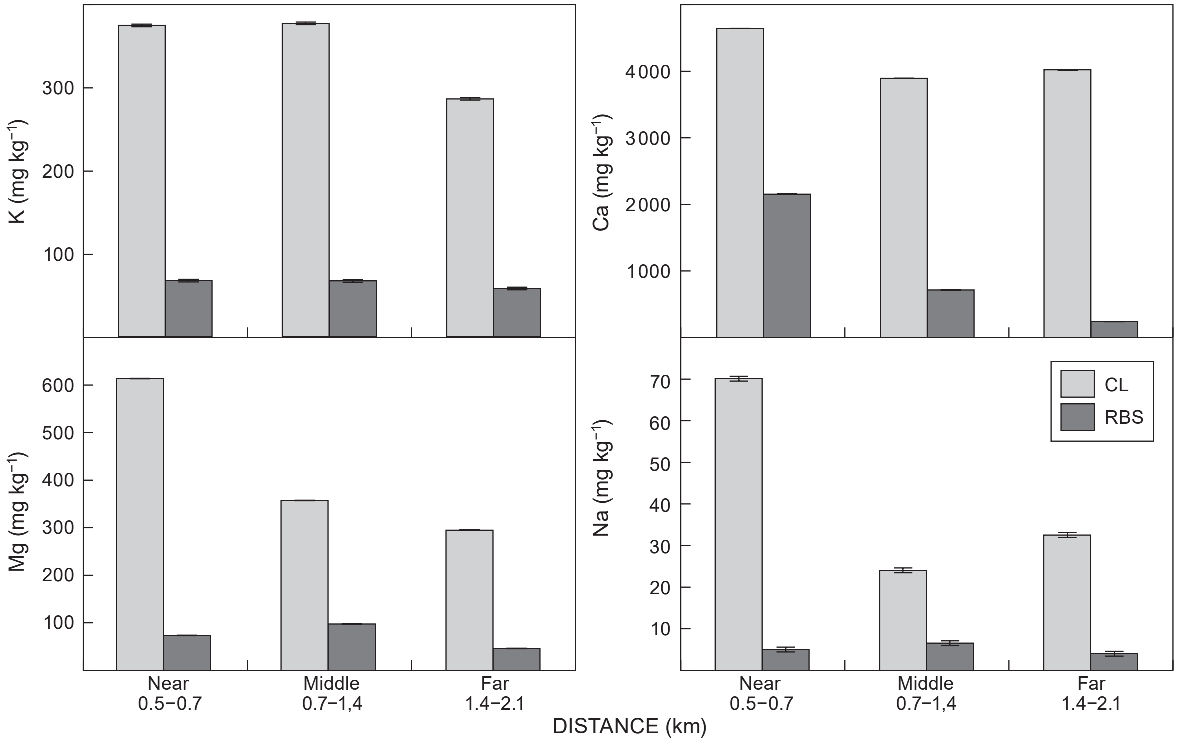

Figure 2: Influence of soil type (clay loam (CL) and red brown sand (RBS)) and distance (Near = 0.5–0.7 km; Middle = 0.7–1.4 km; Far = 1.4–2.1 km) from homesteads on soil potassium (K), calcium (Ca), magnesium (Mg) and sodium (Na). Error bars: K = 1.60; Ca = 0.720; Mg = 0.577; Na = 0.577.

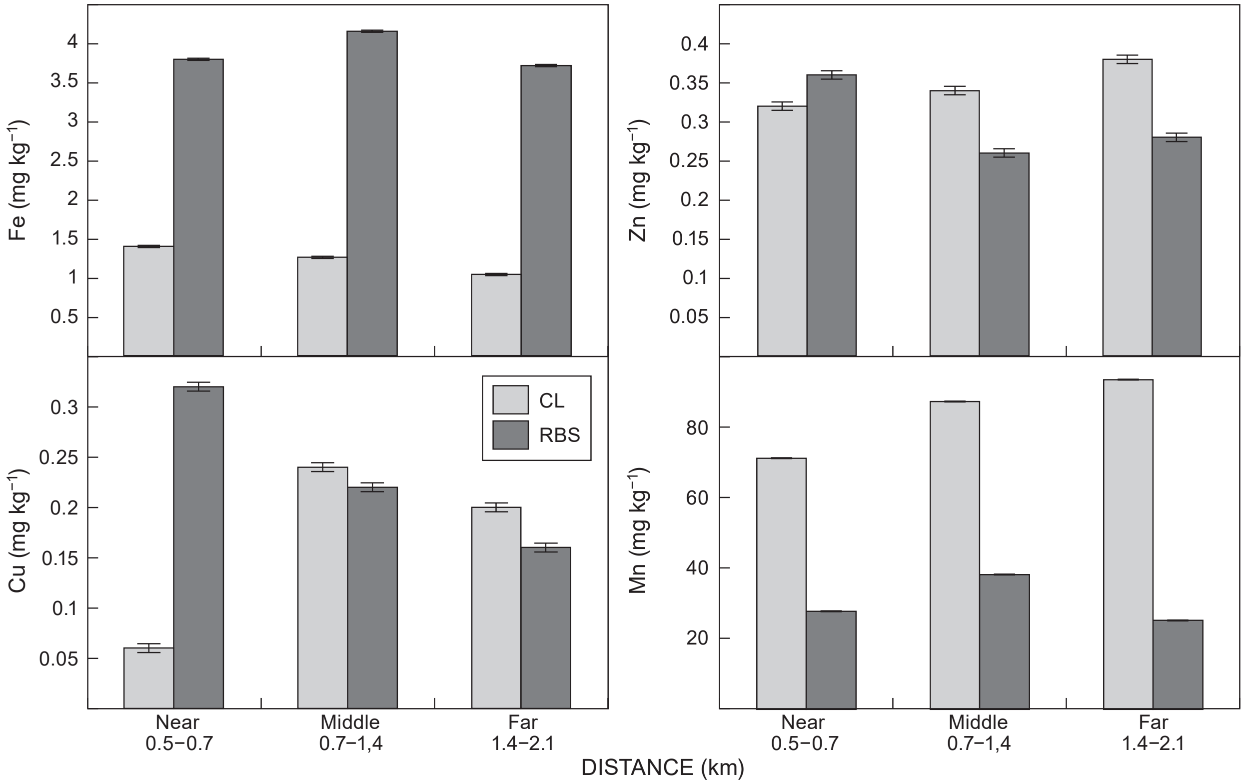

Figure 3: Influence of soil type (clay loam (CL) and red brown sand (RBS)) and distance (Near = 0.5–0.7 km; Middle = 0.7–1.4 km; Far = 1.4–2.1 km) from homesteads on soil iron (Fe), zinc (Zn), copper (Cu) and manganese (Mn). Error bars: Fe = 0.014; Cu = 0.004; Zn = 0.005; Mn = 0.120.

Table 5: Effects of species and distance from homesteads on chemical composition (g/kg DM) of grass species found in the clay loam (CL) soil type areas.

Species	Organic matter	Crude protein	Neutral detergent fibre	Acid detergent fibre	Acid detergent lignin
Aristida congesta	812.3^{d}	55.0^{e}	767.18^{abcdef}	461.05^{bc}	79.15^{de}
Eragrostis pilosa	867.8^{abc}	54.4^{e}	672.2^{e}	405.4^{d}	82.5^{d}
Cynodon dactylon	841.8^{bcd}	76.6^{b}	753.7^{abcde}	386.3^{d}	69.2^{de}
Eragrostis echinochlodea Stapf.	849.1^{abcd}	70.9^{bc}	728.0^{cde}	401.6^{d}	63.9^{e}
Eragrostis cylindriflora 2 Hochst.	815.3^{d}	99.5^{a}	743.9^{bcde}	326.1^{e}	63.2^{e}
Cymbopogon pospischilii L.	843.7^{bcd}	58.1^{de}	681.0^{de}	377.1^{d}	69.6^{de}
Themeda triandra Forssk.	866.3^{abc}	34.8^{g}	772.5^{abcd}	472.7^{bc}	71.2^{de}
Aristida diffusa Trin	887.6^{a}	35.8^{g}	881.3^{a}	574.6^{a}	117.9^{ab}
Aristida adscensionis L.	883.3^{ab}	37.4^{fg}	834.6^{ab}	568.6^{a}	107.3^{bc}
Eragrostis cylindriflora 1 Hochst.	876.2^{ab}	69.0^{bcd}	806.4^{abc}	501.0^{b}	99.1^{c}
Bothriochloa bladhii (Retz.) S.T.Blake	840.9^{bcd}	31.3^{g}	756.8^{abcde}	543.9^{a}	132.8^{a}
Fingerhuthia africana	866.8^{abc}	55.8^{e}	797.2^{abc}	450.7^{c}	81.2^{d}
Chloris virgata	829.1^{cd}	60.4^{cde}	775.9^{abcd}	481.2^{bc}	98.5^{c}
Panicum maximum	830.1^{cd}	48.3^{ef}	751.3^{bcde}	469.6^{bc}	115.1^{bc}
SEM	13.14	4.00	29.32	13.00	5.31

In a column, means with common superscripts do not differ ($p > 0.05$)
SEM = Standard error of the mean

Table 6: Effects of species and distance from homesteads on chemical composition (g/kg DM) of grass species found in the red brown sand (RBS) soil type areas

Species	Organic matter	Crude protein	Neutral detergent fibre	Acid detergent fibre	Acid detergent lignin
Eragrostis pilosa	888.4^{a}	62^{ab}	746.2^{c}	406.2^{d}	72.6^{d}
Aristida congesta	850.5^{a}	66^{ab}	759.8^{c}	498.0^{abc}	145.8^{ab}
Cynodon dactylon	856.8^{a}	56^{bc}	754.1^{c}	418.2^{d}	130.1^{bc}
Aristida diffusa Trin.	845.4^{a}	54^{bc}	757.1^{c}	525.9^{a}	165.5^{a}
Centropodia glauca	884.6^{a}	53^{bc}	738.4^{c}	404.7^{d}	70.6^{d}
Melinis repens (Willd.) Zizka	859.0^{a}	70^{a}	759.1^{c}	484.1^{bc}	132.4^{b}
Perotis patens	865.1^{a}	49^{c}	792.4^{b}	474.7^{c}	166.4^{a}
Aristida stipitata	905.4^{a}	54^{bc}	809.1^{ab}	503.8^{abc}	150.6^{ab}
Eragrostis echinochlodea Stapf.	851.6^{a}	36^{d}	832.5^{a}	522.5^{ab}	109.7^{c}
Aristida adscensionis L.	730.0^{b}	46^{cd}	799.6^{b}	533.8^{a}	169.0^{a}
SEM	18.4	0.38	10.3	12.4	7.2

In a column, means with common superscripts do not differ ($p > 0.05$)
SEM = Standard error of the mean

influenced by nutrient and moisture availability, which vary with soil type. In addition, nutrient–nutrient interactions, which influence nutrient availability to plants, are directly affected by soil pH. In this study, CL soil had higher pH values (6.0–6.4) compared to RBS soil (4.5–5.5) and thus supported higher grass growth and diversity, a finding that corroborates findings reported by Gillespie et al. (2020). A soil pH of 5.2–8.0 is regarded as optimum for most grasses (Lake 2000). At low soil pH, important elements such as P, Mg and Ca become less available to many plants (Garrison 2002). Indeed, P is most available for plant uptake at pH values from 6.0 to 7.0 (Brady and Weil 1999). Quan and Liang (2017) stress that variation in soil types is normally based on texture and chemical properties. Clay loam soil had higher N, P, OC, K and micro mineral levels than in RBS soil. This might have contributed to the greater diversity and abundance of grass species in CL soil when compared to RBS soil. Organic matter is critical for the health and production potential of soil (Aandahl 1981; FAO 2017), which is why grass species were more abundant in CL soil than in RBS soil.

Phosphorus and N content as well as the pH of topsoil did not vary with distance from homesteads. Similarly, Le et al. (2002) found that soil pH was relatively stable irrespective of distance from homesteads in all directions. However, P and N results contradict those of Kavianpoor (2012) and Blank et al. (2007) who reported spatial variation in topsoil minerals. Lempesi et al. (2012) also reported that total soil nitrogen was significantly higher closer to homesteads than in areas further from homes. This could be explained by the fact that soil in heavily grazed areas tends to have higher N content (Lempesi et al. 2012) due to higher levels of animal excrement and urine (Liu et al. 2011).

Grass layer

Approximately 71% of the grasses in the study areas (Table 2) were perennial plants, which was expected, as in

Table 7: Effects of species and distance from homesteads on the *in vitro* ruminal dry matter degradability (g/kg DM) (0, 24 and 48) of grass species growing in clay loam soil

Species	DMD0	DMD24	DMD48
Fingerhuthia africana	94.2^{cdef}	230.7^{de}	351.9^{cd}
Aristida congesta	134.2^{bc}	333.0^{b}	425.7^{b}
Eragrostis cylindriflora 1 Hochst.	96.8^{cdef}	249.0^{cd}	340.5^{cd}
Cynodon dactylon	123.8^{cd}	299.7^{bc}	342.5^{cd}
Bothriochloa bladhii (Retz.) S.T.Blake	104.5^{cde}	302.2^{bc}	386.3^{bc}
Heteropogon contortus	107.3^{cde}	337.8^{b}	328.2^{cd}
Eragrostis superba	92.7^{def}	291.5^{bc}	393.7^{bc}
Eragrostis cylindriflora 2 Hochst.	161.9^{ab}	428.0^{a}	562.0^{a}
Aristida adscensionis L.	71.3^{ef}	252.5^{cd}	300.3^{de}
Eragrostis pilosa	111.6^{cd}	311.1^{bc}	384.5^{bc}
Chloris radiata	118.0^{cd}	290.5^{bc}	373.1^{bc}
Aristida diffusa Trin.	63.5^{f}	191.1^{e}	254.0^{e}
Panicum maximum	116.6^{cd}	303.2^{bc}	385.1^{bc}
Cymbopogon pospischilii L.	176.1^{a}	415.1^{a}	540.6^{a}

In a column, means with common superscripts do not differ ($p > 0.05$).

DMD0 = Dry Matter soluble in water

DMD24 = Dry Matter Degradability at 24 hours after inoculation

DMD48 = Dry Matter Degradability at 48 hours after inoculation

Table 8: Effects of species and distance from homesteads on the in vitro ruminal dry matter degradability (g/kg DM) (0, 24 and 48) of grass species growing in red brown sand soils

Species	DMD0	DMD24	DMD48
Eragrostis pilosa	127.2^{ab}	316.5^{ab}	369.7
Aristida congesta	80.7^{c}	264.8^{cd}	340.9
Cynodon dactylon	118.9^{b}	301.4^{abc}	342.5
Aristida diffusa Trin.	82.2^{c}	273.0^{bcd}	360.3
Centropodia glauca	139.7^{a}	299.1^{abc}	382.9
Melinis repens (Willd.) Zizka	125.7^{ab}	335.0^{a}	409.1
Perotis patens	116.7^{b}	276.6^{bc}	404.3
Aristida stipitata	85.7^{c}	254.4^{cd}	275.3
Eragrostis echinochlodea Stapf	72.7^{c}	277.5^{bc}	366.5
Aristida adscensionis L.	69.8^{c}	227.4^{d}	305.2

In a column, means with common superscripts do not differ ($p > 0.05$)
DMD0 = Dry Matter soluble in water
DMD24 = Dry Matter Degradability at 24 hours after inoculation
DMD48 = Dry Matter Degradability at 48 hours after inoculation

semi-arid areas perennial grasses tend to be more prevalent than annual plants (Lesoli 2011). These species tend to be drought tolerant and are important for herbivores in these areas. In study sites with CL soil, perennial grasses (whose grazing value ranged from low to medium), were more common when compared to sites with the RBS soil type, due to better moisture-holding capacity than in the RBS soil. The availability of these perennial grass species (as opposed to annual grass species) can help increase the OC content of soils, increase soil friability and enhance water-stable aggregation (Chan et al. 2001). Perennial grasses also help preserve fragile hard-setting soils in low precipitation sites. The ecological status of grasses shows that CL soils were covered by increaser i to increaser iii species with only a few species being decreasers. Indeed, increaser i to increaser iii species have been reported to be abundant in under-grazed and overgrazed rangelands (van Oudtshoorn 2014). The presence (dominant and common) of some unpalatable species such as *C. pospischilii* and *Aristida* spp. provides evidence that the current study areas were overgrazed or disturbed. *Cynodon dactylon* was the only palatable species found in both soil types, which provided evidence of its tolerance to defoliation as well as its inaccessibility to livestock due to its height (prostrate growth habit)(van Oudtshoorn 2014). *Themeda triandra* Forssk. and *Panicum maximum* Jacq. were the only perennial palatable species found in the CL soil type areas. Though these species' availability indicates a veld in good condition (Zacharias 1990), *T. triandra* was found in the middle and sites far from homesteads, where there was light to medium bush encroachment and less access for livestock. *Panicum maximum* was only found under trees where there is little or no access by livestock.

There was a direct correlation between soil fertility status and species occurrence in selected areas. Ben-Shahar and Coe (1992) stated that the nutrient levels of soil influence the grass species abundance and distribution. In return, the abundance and species diversity also affect soil fertility through nutrient inputs and nutrient retention effects (Dybzinski et al. 2008). The CL sites, which had high diversity of species, had better soil fertility status when compared to the RBS soil type. The RBS sites had *Aristida spp.* and *E. pilosa* grasses in greater abundance relative to CL sites, as the *Aristida* species grow well in disturbed soils (van Oudtshoorn 2014). The same author (van Oudtshoorn 2014) indicated that *E. pilosa* is dominant in areas that are underlain by highly weathered soils and in sandy textured soils that lack any significant soil profile development, especially in semi-arid and arid areas.

The abundance of highly desirable species increased with distance from homesteads, which could be attributed to a decrease in grazing pressure on vegetation on the CL soil type. Similarly, at RBS soil sites unpalatable species were most common close to homesteads, with the abundance decreasing in a distal direction. In general, and as expected, lower biomass accumulation was found in the areas near the homesteads, where the grazing pressure was higher. Adler and Hall (2005) stressed that forage availability is always reduced to low levels near resting areas and this can bring a monotonal relationship between distance from certain locations (watering point, resting and homesteads areas) and utilisation. This explains why the biomass and diversity of high grazing value plants decreased with increasing proximity to homesteads.

Chemical composition and ruminal fermentation of grasses

The interaction between soil type and plant species affects the nutritive value of grasses in many rangelands (Manyedi et al. 2017, Ben-Shahar and Coe 1992). Opposite to our findings, only plant species had an effect to the nutritive value of grass species. The grasses from our study areas were harvested at maturity stage where it might be difficult to assess if soil type might have contributed to the fertility of the grasses. This could explain why most grasses harvested from the more fertile CL soil did not necessarily contain higher levels of protein than those harvested from the less fertile RBS. This finding is in line with the findings by Ben-Shahar and Coe (1992), who also failed to establish a relationship between soil nutrients and grass nutritive value. Except for *C. pospischilii*, all grass species had NDF content above 700 g/kg DM. During the early growing season, the proportion of cell crude protein (CP) content of grasses tends to be higher, while the proportion of cell wall components (NDF and ADF) is lower, thus contributing to a higher nutritive value. The reverse happens late in the growing season, when growth rates decline. As the growth rates decline the NDF and ADF content increases and the CP declines (Ekaya 2001). In addition to higher CP content, *C. dactylon* and *E. cylindriflora* 2 Hochst grasses had lower ADF and ADL content compared to other grass species. However, these grass species play little or no ecological role as they were not dominant in the studied communal areas.

In vitro ruminal DM degradability values of *C. pospischilii* and *E. cylindriflora* 2 Hochst growing in the CL soil type were higher than in other grasses. This could be explained by the high CP content of the grasses (Perez-Corona et al. 1998). This relationship between CP content of forages and DMD has been previously demonstrated (Oh et al. 2008). Higher forage protein promotes greater rumen microbial activity leading to higher rates and extent of fermentation (Mnisi and Mlambo 2016). Despite the higher DMD values observed in *C. pospischilii*, it is important to note that this grass species is largely neglected by animals during the rainy season due to its poor grazing value (Smit and Rethman 1990, van Oudtshoorn 2014). Its poor palatability is due to the presence of volatile oils, which has a bitter taste and thus will only be grazed during the dry periods when animals run out of alternatives (Tshabalala et al. 2010). The DMD observed for *C. pospischilii* in this study are similar to that reported by Fourie et al. (1985). The low ADL content of *C. pospischilii* might be the reason why this substrate had high DMD, since lignin is known to interfere with the rumen fermentation of forages. Indeed, van Soest (1994) reported that lignin is the major cause of poor degradation of fibrous polysaccharides in the rumen, as it acts as a physical barrier to digestion and also contains chemical bonds that cannot be broken down by normal rumen microbial flora (Buxton and Redfearn 1997). As such, grasses with lower lignin content tend to be digested more and promote greater animal productivity.

Conclusion

Overgrazing is prevalent in the studied communal areas. The data collected indicate that overgrazing and low plant cover contribute negatively to soil quality as measured by soil nutrients in both soil types. There was a reduction in the occurrence of most palatable species in the study areas and a general increase in the distribution of grass species that cannot be used by livestock. The grazing areas need to be differently managed to avoid overgrazing. To maximise nutritional benefit for livestock from these grazing areas, grazing should be scheduled during the growing stages of the most common grass species. *Cynodon dactylon* and *E. cylindriflora* 2 Hochst grass species had higher CP content and ruminal degradability and thus should be targeted for use in rangeland restoration practices across the two soil types.

Conflict of interest — The authors do not have any conflicts of interest.

Acknowledgements — The authors acknowledge the financial and material support provided by North-West University for the first author's studies.

ORCID iDS

KE Ravhuhali— https://orcid.org/0000-0002-5303-7320
V Mlambo— https://orcid.org/0000-0002-0799-3899
TS Beyene— https://orcid.org/0000-0002-7666-8352
LG Palamuleni— https://orcid.org/0000-0002-1054-6942

References

Aandahl AR. 1981. *Soils of the Great Plains: Land use, Crops and Grasses*. Lincoln: University of Nebraska Press.

Adler P, Hall S. 2005. The development of forage production and utilisation gradients around livestock watering points. *Landscape Ecology* 20: 319–333.

Ahamefule FO, Obua BE, Ibeawuchi JA, Udosen NR. 2006. The nutritive value of some plants browsed by cattle in Umudike, South-Eastern Nigeria. *Pakistan Journal of Nutrition* 5: 404–409.

AOAC. 2012. *Method number 973.18, In Official Methods of Analysis of AOAC International* (16th edn). Arlington: Association of Official Analytical Chemists.

AOAC. 2012. *Method number 976.06. In Official Methods of Analysis of AOAC International* (16th edn). Arlington: Association of Official Analytical Chemists.

Ashworth J, Keyes D, Kirk R, Lessard R. 2001. Standard procedure in the hydrometer method for particle size analysis. *Communications in Soil Science and Plant Analysis* 32:5/6, 633–642

Baker, K.F., 1976. The determination of organic carbon in soil using a probe-colorimeter. *Lab Practice* 25: 82–3.

BenShahar, R, Coe, M.J. 1992. The relationship between soil factors, grass nutrients, and the foraging behavior of wildebeest and zebra. *Oecologia* 90: 422–428.

Bista DR, Heckathorn SA, Jayawardena DM, Mishra S, Boldt JK. 2018. Effects of drought on nutrient uptake and the levels of nutrient-uptake proteins in roots of drought-sensitive and-tolerant grasses. *Plants*, 7(2): 28.

Blank RR, Chambers J, Roundy B, Whittaker A. 2007. Nutrient availability in rangeland soils: influence of prescribed burning, herbaceous vegetation removal, over-seeding with *Bromus tectorum*, season, and elevation. *Rangeland Ecology and Management* 60: 644–655.

Brady NC, Weil RR. 1999. *The Nature and Properties of Soils*. Upper Saddle River: Prentice Hall.

Britz M-L. 2004. The effects of soil type and management strategy on vegetation structure and function in a semi-arid savanna, South Africa. Thesis (MSc). Stellenbosch University, South Africa.

Buxton DR, Redfearn DD. 1997. Plant limitations to fiber digestion and utilization. *Journal of Nutrition* 127: 814–818.

Chan KY, Bowman AM, Smith W, Ashley R. 2001. Restoring soil fertility of degraded hardsetting soils in semi-arid areas with different pastures. *Australian Journal of Experimental Agriculture* 41: 507–514.

Dangal SR, Tian H, Lu C, Pan S, Pederson N, Hessl A. 2016. Synergistic effects of climate change and grazing on net primary production of Mongolian grasslands. *Ecosphere* 7: 01274.

Dybzinski R, Fargione JE, Zak DR, Fornara D, Tilman D. 2008. Soil fertility increases with plant species diversity in a long-term biodiversity experiment. *Oecologia* 158, 85–93.

Ekaya WN. 2001. Nutritional characteristics of selected grassland browse species from Kenya pastoral ecosystems. *Journal of Human Ecology* 12: 171–175.

FAO. 2017. *Soil Organic Carbon: the hidden potential*. Rome: Food and Agriculture Organization of the United Nations.

FASS. 2010. Guide for the care and use of agricultural animals in research and teaching. 3rd edn. Champaign: Federation of Animal Sciences Societies.

Fourie JH, Opperman DPJ, Roberts BR. 1985. Evaluation of the grazing potential of grass species in Tarchonanthus veld of the Northern Cape. *Grassland Society of Southern Africa* 2: 13–17.

Fraterrigo JM, Turner MG, Pearson SM, Dixon P. 2005. Effects of past land use on spatial heterogeneity of soil nutrients in southern Appalachian forests. *Ecological Monographs* 75: 215–230.

Garrison S. 2002. Where it's at. Physical and chemical processes of water and solute transport/retention in soil. Selim HM and Sparks DL (eds), *Soil Science Society of America* 16: 1337–1338.

Gillespie DP, Kubota C, Miller SA. 2020. Effects of Low pH of Hydroponic Nutrient Solution on Plant Growth, Nutrient Uptake, and Root Rot Disease Incidence of Basil (Ocimum basilicum L.), *American Society for Horticultural Science* 55(8): 1251–1258.

Grayston SJ, Campbell CD, Bardgett RD, Mawdsley JL, Clegg CD, Ritz K, Griffiths BS, Rodwell JS, Edwards SJ, Davies WJ, Elston DJ, Millard P. 2004. Assessing shifts in microbial community structure across a range of grasslands of differing management intensity using CLPP, PLFA and community DNA techniques. *Applied Soil Ecology* 25: 63–84.

Hannusch, HJ, Rogers, WE, Lodge, AG, Starns, HD, Tolleson, DR. 2020. Semi-arid savanna herbaceous production and diversity responses to interactive effects of drought, nitrogen deposition, and fire. *Journal of Vegetation Science* 31: 255–265.

Hufford KM, Mazer SJ, Hodges SA. 2014. Genetic variation among mainland and island populations of a native perennial grass used in restoration. *AoB Plants* 6: plt055.

Jackson ML. 1970. *Nitrate-nitrogen. Soil Chemical Analysis*. 6th edn. Englewood Cliffs: Prentice-Hall. pp 326–330.

Kavianpoor H, Esmali OA, Jafarian JZ, Kavian A. 2012. Spatial variability of some chemical and physical soil properties in Nesho mountainous rangelands. *American Journal of Environmental Engineering* 2: 34–44.

Kramer HAC, Montgomery DM, Eckhart VM, Geberm MA. 2011. Environmental and dispersal controls of an annual plant's distribution: How similar are patterns and apparent processes at two spatial scales? *Plant Ecology* 212: 1887–1899.

Lake B. 2000. *Understanding soil pH*. Leaflet No.2. Leeton: NSW DPI Yanco Agricultural Institute.

Le D, Nguyen Ngoc M, Nguyen Cong V. 2002. *Soil environments affected by copper recycling activities, Dai Dong village, Van lam District, Haoi Hun Province*, Vietnam ESCAP – IWMI Seminar on Environmental and Public Health Risks Due to Contamination of Soils, Crops, Surface and Ground water from Urban, Industrial and Natural Sources in South East Asia, Hanoi, Vietnam, 10–12 December 2012.

Lempesi A, Hormova E, Orfanoudakis M, Korakis G, Kyriazopoulos AP. 2012. *Soil properties along grazing gradients in an open canopy oak Forest*. Proceedings of 9th European dry grassland meeting (EDGM) Prespa, Greece, 19–23 May 2012.

Lesoli MS. 2011. Characterisation of communal rangeland degradation and evaluation of vegetation restoration techniques in the Eastern Cape, South Africa. Doctoral thesis, University of Fort Hare, Alice, South Africa.

Liu T, Nan Z, Hou F. 2011. Grazing intensity effects on soil nitrogen mineralization in semi-arid grassland on the Loess Plateau of northern China. *Nutritional Cycling in Agroecosystems* 91: 67–75.

Manyedi G, Ravhuhali KE, Sebolai TM, Motsei LE, Keoletile, MI. 2017. Assessment of grass species composition and nutritive value as influenced by soil characteristics in two different grazing areas under North West Province South Africa. GSSA Annual Congress, 26 July 2017.

Miranda JDD, Armas C, Padilla FM, Pugnaire FI. 2011. Climatic change and rainfall patterns: effects on semi-arid plant communities of the Iberian Southeast. *Journal of Arid Environments* 75: 1302–1309.

Mnisi CM, Mlambo V. 2016. Influence of harvesting site on chemical composition and potential protein value of Acacia erioloba, Acacia nilotica and Ziziphus mucronata leaves for ruminants. *Journal Animal Physiology and Animal Nutrition* 101: 994–1003.

Mucina L, Rutherford MC. 2006. *The vegetation of South Africa, Lesotho and Swaziland*. Pretoria: South African National Biodiversity Institute.

Oh YK, Kim JH, Kim KH, Choi CW, Kang SW, Nam IS, Kim DH, Song MK, Kim CW, Park KK. 2008. Effects of level and degradability of dietary protein on ruminal fermentation and concentrations of soluble non-ammonia nitrogen in ruminal and omasal digesta of Hanwoo steers. *Asian–Australian Journal Animal Science* 21: 392–403.

Olsen SR, Sommers LE. 1982. Phosphorus. In: Page AL (ed.), *Methods of Soil Analysis: Part 2. Chemical and Microbiological Properties*. Madison: American Society of Agronomy, Soil Science Society of America. pp 403-430.

Perez-Corona M, Vazquez de Aldana BR, Criado BG, Ciudad, AG. 1998. Variations in nutritional quality and biomass production of semiarid grasslands. *Journal of Range Management* 51: 570–576.

Polley HW, Bailey DW, Nowak RS, Stafford-Smith M. (2017) Ecological Consequences of Climate Change on Rangelands. In: Briske D (ed.) *Rangeland Systems*. Springer Series on Environmental Management. Cham: Springer.

Pulungan MA, Suzuki S, Gavina MKA, Tubay JM, Ito, H, Nii, M, Ichinose G, Okabe T, Ishida A, Shiyomi M, Togashi T. 2019. Grazing enhances species diversity in grassland communities. *Scientific Reports* 9: 1–8.

Quan M, Liang J. 2017. The influences of four types of soil on the growth, physiological and biochemical characteristics of *Lycoris aurea* (L' Her.) herb. *Scientific Reports* 7: 1–8.

Rahmanian S, Hejda M, Ejtehadi H, Farzam M, Memariani F, Pyšek P. 2019. Effects of livestock grazing on soil, plant functional diversity, and ecological traits vary between regions with different climates in northeastern Iran. *Ecology and Evolution* 9: 8225–8237.

Ravhuhali KE, Mlambo V, Beyene TS, Luvhengo U, Palamuleni L. 2020a. Socio-cultural perceptions of communal farmers towards rangeland degradation in selected localities of South Africa. *Range Management and Agroforestry* 41(1): 147–155.

Ravhuhali KE, Mlambo V, Beyene TS, Palamuleni L. 2020b. Effects of soil type on density of trees and nutritive value of tree leaves in selected communal areas of South Africa. *South African Journal of Animal Science* 50: 88–98.

Särkijärvi S, Sormunen-Cristian R, Heikkilä T, Rinne M, Saastamoinen M. 2012. Effect of grass species and cutting time on *in vivo* digestibility of silage by horses and sheep. *Livestock Science* 144: 230–239.

SAS. 2010. *Statistical Analytical Systems*, Users Guide. Cary: SAS Institute Inc.

Škornik, S, Vidrih M, Kaligarič M. 2010. The effect of grazing pressure on species richness, composition and productivity in North Adriatic Karst pastures. *Plant Biosystems*, 144(2): 355–364.

Smit GN, Rethman NFG. 1990. Association of *Cymbopogon plurinodis* with the clay content of soil in the Sourish Mixed Bushveld. *Journal of the Grassland Society of Southern Africa* 7: 64–66.

Soininen J, Hillebrand H. 2007. Disentangling distance decay of similarity from richness gradients: response to Baselga. *Ecography* 30: 842–844.

Tefera S, Snyman H.A, Smit GN. 2005. Rangeland dynamics in southern Ethiopia:(1) Botanical composition of grasses and soil characteristics in relation to land-use and distance from water in semi-arid Borana rangelands. *Journal of Environmental Management* 85: 429–442

Tefera S, Dlamini BJ, Dlamini AM. 2010. Changes in soil characteristics and grass layer condition in relation to land management systems in the semi-arid savannas of Swaziland. *Journal of Arid Environment* 74: 675–684.

Tshabalala T, Dube S, Lent PC. 2010. Seasonal variation in forages utilized by the African buffalo (Syncerus caffer) in the succulent thicket of South Africa. *African Journal of Ecology* 48: 438–445.

van Oudtshoorn FP. 2014. *Guide to grasses of South Africa*. Pretoria: Briza Publications.

Van Soest PJ, Robertson JB, Lewis BA. 1991. Methods for dietary fiber, neutral detergent fiber, and non-starch polysaccharides in relation to animal nutrition. *Journal of Dairy Science* 74: 3583–3597.

Van Soest PJ. 1994. *Nutritional Ecology of the Ruminant*. Ithaca: Cornell University Press. pp 476.

van Reeuwijk LP. 1992. *Procedures for soil analysis*. 3rd edn. Wageningen: International Soil Reference and Information Center (ISRIC). pp 34.

Várallyay G. 2010. The impact of climate change on soils and on their water management. *Agronomy Research* 8 (II): 385–396.

Zacharias, PJK. 1990. *Acocks Notes. Key grasses of South Africa*. Howick: Grassland Society of Southern Africa.

Received 14 September 2020, revised 19 May 2021, accepted 20 May 2021
Associate Editor: Linus Franke