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Effects of soil type on density of trees and nutritive value of tree leaves in selected communal areas of South Africa

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Abstract

This study aimed to describe the distribution and nutritive value of woody species growing in clay-loamy and red-brown sand from selected localities of North West, South Africa. Three 2.2 km transects, radiating from homesteads, which served as replicates, were established at each of four selected grazing areas. Nine 10 × 10 m homogenous vegetation units (HVU), 20 m apart, were marked in each transect. Woody plant density, height and canopy cover (CC), were recorded, and chemical properties and degradability via in vitro ruminal fermentation of harvested leaves were measured. Raisin bush (*Grewia flava*), Buffalo thorn (*Ziziphus mucronata*) and Camel thorn (*Vachellia erioloba*) were the common species across both soil types. Soil type influenced ($P < 0.05$) plant density, CC, total tree equivalent (TTE) and plant height. Areas with red-brown sandy soil had higher ($P < 0.05$) total plant density (827.7 plant/ha), CC (9.6%) and TTE (2886.4 TTE/ha) than those with clay-loamy soil. *Vachellia erioloba* leaves in clay-loamy soil had the highest ($P < 0.05$) crude protein content (151.2 g/kg DM). Leaves of *Searsia lancea* species that were harvested from both the clay-loamy and red-brown sandy soils had the highest ($P < 0.05$) amounts of condensed tannins (0.915 AU₅₅₀/200 mg and 0.917 AU₅₅₀/200 mg, respectively). *Searsia lancea* leaves had the lowest ($P < 0.05$) in vitro ruminal nitrogen degradability values in both soil types. The leaves of *Z. mucronata* and *G. flava* leaves have potential as protein supplements for ruminants owing to their higher crude protein content and in vitro ruminal N degradability.

Keywords: canopy cover, feeding value, plant height, semi-arid, species diversity, tree equivalent

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Introduction

Cattle, sheep and goats are mostly reared on communal rangelands in semi-arid areas where browse species constitute the major feed resource, but may also be a major threat to rangeland productivity. Indeed, impenetrable thickets, consisting mainly of *Acacia spp* and *Dichrostachys cinera*, are known to reduce grass cover in the semi-arid areas (Tolsma *et al.*, 1987). Plant distribution in rangelands is affected by factors such as climate, soil type and biotic interactions (human and livestock effects) (Steege *et al.*, 2003; Okiror *et al.*, 2012). These factors also determine which plant species are filtered into the local community, and thus have a direct effect on the ecological balance of the rangeland.

Woody plants have appropriate agronomic characteristics to contribute browse products of high nutritional value for ruminants reared in semi-arid communal rangelands. They are known to maintain higher levels of protein and minerals during growth than grasses (Shelton, 2004). Utilization of these species by livestock in most areas has been low despite the known benefits such as reducing bush encroachment and improving animal performance in semi-arid areas. The presence of anti-nutritional factors in tree foliage has

been shown to contribute to low voluntary intake of browse products (Mlambo *et al.*, 2015). Establishment of the nutrient concentration and other nutritive value indicators of herbage from natural browse plants is essential for efficient and sustainable production of animals off the veld (Tefera *et al.*, 2008). Furthermore, assessment of the distribution and status of native vegetation is essential for sustainable management of these ecological systems. There is also a need for continuous screening of browse trees to identify those with potential for animal feeding in order to increase the productivity of ruminants. Despite the heavy dependency on rangelands by communal livestock, little research has been done on the distribution and nutritive value of woody species in most communal areas around the country. Indeed, the distribution and potential nutritive value of woody species in most communal rangelands of North West have not been studied. Thus, the objective of the study was to determine the distribution and nutritive value of browse trees in selected localities of that province.

Material and Methods

The study was conducted on four communal rangelands (grazing areas) in Ngaka Modiri Molema district of the province of North West, South Africa. These sites were selected because field observations before starting with the trials had shown that they were highly overgrazed or mismanaged and spanned two soil types. The two sites with clay-loamy soil type sites were Tsetse (S25°44.776 E025°40.533) and Six Hundred (S25°43.133 E025°38.597) while those with red-brown sandy soil type were Makgobistad (S25°46.198 E025°04.822) and Loporung (S25°46.909 E024°59.035) (Figure 1). The areas receive mean annual rainfall ranging from 400 to 450 mm, whereas the mean annual temperature varies between 2 °C and 36 °C. The landscape in Tsetse and Six-hundred is undulating rather than flat and ranges in altitude from 1296 to 1309 m above sea level with dry highveld grassland vegetation (Mucina & Rutherford, 2006). The landscape in Makgobistad and Loporung is also undulating and ranges in altitude from 1117 to 1182 m above sea level with Eastern Kalahari Bushveld vegetation. Most ruminants that graze in these areas are goats and cattle.

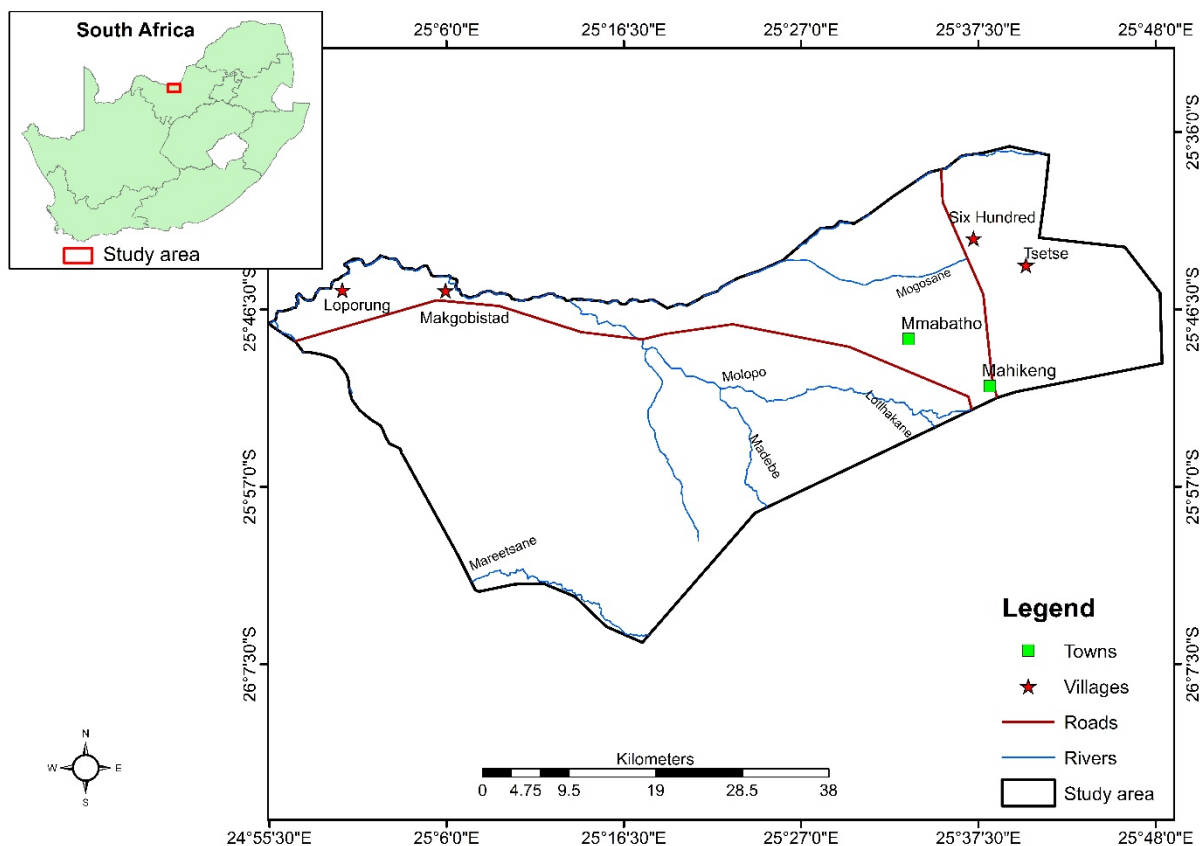


Figure 1 Map locating the Loporung, Makgobistad, Six Hundred and Tsetse study sites in North West, South Africa

Data collection was conducted between January and May 2015 using three 2.2 km transects, which served as replicates. These radiated from homesteads at each of the selected grazing areas. The three transects were placed at least 200 m from each other. Along each transect, points were marked at intervals of 500 - 700 m from the homesteads to form nine sampling sub-transects. Three 10 x 10 m homogenous vegetation units were marked in each sub-transect, 20 m apart, resulting in a total of 27 HVUs per grazing area, from which density, height, canopy diameter of individual woody plants and chemical composition of leaves were determined. The identification of the plant was carried out as described by Van Wyk *et al.* (2012). The chemical composition of dominant species (composition of above 13%) and common species (composition of above 3%) leaves was also determined. All rooted live woody plants were recorded and counted in each HVU. Within each sub-plot, trees were identified, counted and classified based on height as seedlings (0 - 1 m), young shrubs (1 - 1.5 m), mature shrubs (1.5 - 2 m), young trees (2 - 3 m), and mature trees (>3 m). Within each HVU, the canopy diameter of every woody plant species was measured along two axes (length (L) and width (W) perpendicular to each other. Determination of the CC percentage was done using this equation (Blozan, 2006):

$$\text{Canopy cover} = \left(\frac{\pi}{2}L + \frac{\pi}{2}W \right) / 300 \text{ m} \times 100$$

When an overlap was encountered between the canopies of adjacent woody plants, the length of the overlap was subtracted from the length or width of either of the plants. Total tree equivalent was calculated by dividing the total tree length by 1.5.

Leaves were harvested from common browse tree species (above 3% distribution) (five individual trees per species) that were identified from each grazing communal area. Leaf samples were oven dried at 60 °C until constant weight, and ground to pass through a 2-mm sieve. Milled samples were stored in airtight plastic bags pending chemical analysis and *in vitro* ruminal fermentation. Dry matter (DM) and organic matter (OM) content were determined according to method 973.18 (AOAC, 2012), whereas nitrogen (N) content was determined following the standard macro-Kjeldahl (AOAC, 2012 method 976.06) and crude protein (CP) was equal to 6.25*N. The procedures described by Van Soest *et al.* (1991) were used to determine neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid detergent lignin (ADL). Sodium sulphide and heat-stable bacterial α -amylase were used for NDF analysis. The fibre fractions were expressed inclusive of residual ash. Soluble phenolics and soluble condensed tannins were assayed according to Makkar (2003) and Porter *et al.* (1986), respectively. Soluble phenolics were expressed in μg of tannic acid equivalents (μg TAE). The soluble condensed tannin concentration results were reported as absorbance units (AU) per 200 mg sample.

In vitro ruminal DM and N degradation of browse species leaves were determined using the ANKOM Daisy^{II} incubator (ANKOM Technology Corp, Fairport, NY). Rumen fluid was collected from a one Bonsmara cow that was fed a diet containing lucerne (912.6, 773.5, 459.6, 335.9, 91.9, 221.4, and 139.1 g/kg DM for DM, OM, NDF, ADF, ADL, CP, and ash, respectively) and buffalo grass (959.7, 918.2, 738.2, 388.3, 80.76, 60.75, and 41.5 g/kg for DM, OM, NDF, ADF, ADL, CP, and ash, respectively). Zero-hour samples of the leaves from each species were soaked in warm (39 °C) water for 20 minutes and then dried at 105 °C. Additional samples were inoculated in rumen fluid, withdrawn at 24, 36, and 48 hours, washed with cold water for 20 minutes and dried at 105 °C to determine DM degradability. To determine N degradability, N in DM residues was determined by the macro-Kjeldahl method (AOAC, 2012 method 976.06) and the loss in N from incubated substrate was estimated as degradable N. The fistulated animal was cared for according to the guidelines of the institution and of the Federation of Animal Science Societies (FASS, 2010) for the care and use of agricultural animals in research and teaching. Ethical approval was obtained from North-North-West University Animal Research Ethics Committee, approval number NWU-00126-13-A9.

Effects on total tree plant densities, CC, height class distribution and TTE were evaluated using a one-way analysis of variance (SAS, 2010). The analysis was designed to test the effect of soil type on parameters according to this general linear model:

$$Y_{ij} = \mu + S_i + \varepsilon_{ij}$$

Where: Y_{ij} is the response variable (height, total tree plant density, CC, height class distribution and TTE),

μ is overall mean,

S_i is the effect of soil type, and

ε_{ij} was the error term associated with observation ijk , assumed to be normally and independently distributed.

Chemical composition and *in vitro* ruminal fermentation data were analysed (SAS, 2010) to test the effect of plant species (four species) and soil type (two soil types represented by two sites each) according to the following general linear model:

$$Y_{ijk} = \mu + P_i + S_j + (P \times S)_{ij} + \varepsilon_{ijk}$$

Where: Y_{ijk} is the response variable (density of common species, chemical composition and *in vitro* ruminal degradability),

μ is overall mean,

P_i is the effect of plant species,

S_j is the effect of soil type,

$(P \times S)_{ij}$ is the interaction between plant species and soil type, and

ε_{ijk} is the error term associated with observation ijk and assumed to be normally and independently distributed.

Differences among means were assessed by the method of least significant differences at $P=0.05$).

Results

A total of 21 browse species were identified across the two soil types (Tables 1). Soil type and tree species interacted to influence ($P < 0.05$) plant density (Table 2). *Grewia flava* and *Vachellia erioloba* dominated, while *Ziziphus mucronata* was common in both clay-loamy and red-brown sand soils. *Grewia flava* plants were the most abundant species ($P < 0.05$) (168.5 species/ha) in red-brown sand soil. The density of *V. erioloba* tree species tended to be higher (75.9 plants/ha) in red-brown sand soil compared with clay-loamy soil (48.2 plants/ha).

Table 1 Scientific and vernacular names, growth forms, browse values of woody plants identified in the Loporung, Makgobistad, Six Hundred and Tsetse study sites in North West, South Africa

Scientific name	Common or vernacular name ¹	Growth form ²	Herbivores	Preferred plant part
<i>Bosia albitrunca</i>	Motlopi (Tsw)	T	Cattle and game	Leaves
<i>Dichrostachys cinerea</i>	Moselesele (Tsw) Sickie bush	S	Goats	Leaves
<i>Euclea divinorum</i>	Motlhakola (Tsw)	S	-	-
<i>Grewia flava</i>	Moretwa (Tsw) Brandy bush	T	Goats and game	Leaves and fruits
<i>Grewia monticola</i>	Moretlwa (Tsw)	S	Goats	Leaves
<i>Grewia hexamita</i>	Mukunukunu (V)	S/T	Goats/cattle/ sheep	Leaves
<i>Gymnosporia Buxifolia</i>	Motlhonu (Tsw)	S	-	-
<i>Melia azedarach</i>	Muserenga (V)	T	Cattle and goats	Leaves
<i>Peltophorum africanum</i>	Mosetlha (Tsw)	T	Goat/cattle	Leaves and pods
<i>Searsia lancea</i>	Mosilabele (Tsw)	T	Cattle, goats, game	Leaves
<i>Searsia leptodictya</i>	Mogogobadimo (Tsw)	T	Cattle/goat/game	Leaves
<i>Senegalia caffra</i>	Moruthare (Tsw)	T	Cattle	Leaves
<i>Senegalia galpini</i>	Mongangatau (Tsw)	T	Goats and cattle	Leaves/pods
<i>Senegalia mellifera</i>	Monga (Tsw)	S	Goats and Cattle	Leaves and pods
<i>Terminalia Sericea</i>	Mogonono (Tsw)	T	-	-
<i>Vachellia erioloba</i>	Mogotho (Tsw)/Camel thorn	T	Goats, cattle game	Leaves and pods
<i>Vachellia hebaclada</i>	Sikhi (Tsw)	S	Goats	Leaves/pods
<i>Vachellia karoo</i>	Mooka (Tsw)	S	Goats/Cattle	Leaves/pods
<i>Vachellia nilotica</i>	Motsha (Tsw)/ Black thorn	T	Goats and game	Leaves and pods
<i>Vangueria infausta</i>	Mothwanyê or Mmilo (Tsw);	S/T	-	-
<i>Ziziphus mucronata</i>	Mokgalo (Tsw)/Buffalo thorn	T	Cattle and goats	Leaves and pods

¹Common or vernacular: Tsw: Tswana; V: Venda

²Growth form: T: tree; S: shrub

Table 2 Effects of soil type on density (number of plants/ha) of selected common tree species in the Loporung, Makgobistad, Six Hundred and Tsetse study sites in North West, South Africa

Tree species	Soil type	
	Clay-loamy	Red-brown sand
<i>Grewia flava</i>	42.9 ^B	168.50 ^{AA}
<i>Vachellia erioloba</i>	48.2	75.9 ^b
<i>Searsia lancea</i>	1.9	3.7 ^c
<i>Ziziphus mucronata</i>	11.1	9.3 ^d
Standard error	21.57	

^{abc} Within a column, means with common lowercase superscripts do not differ ($P > 0.05$)

^{AB} Within a row, means with common uppercase superscripts do not differ ($P > 0.05$)

Soil type influenced total plant density, CC, plant height class distribution and TTE (Table 3). Sites with red-brown sand soil had higher ($P < 0.05$) total plant density (827.7 plant/ha), CC (9.6%), and TTE (2886.4 TTE/ha) than those with clay-loamy soil. Areas with red-brown sandy soil had higher density of seedlings (198.15 plants/ha), young shrubs (231.48 plants/ha), mature shrubs (125.93 plants/ha), young trees (170.37 plants/ha), and old trees (92.59 plants/ha) than clay-loamy soil areas.

Table 3 Overall canopy cover (%), total plant density (number of trees/ha) and total tree equivalents in red-brown sandy and clay-loamy soils species in the Loporung, Makgobistad, Six Hundred and Tsetse study sites in North West, South Africa

Soil type	TPD	CC	TTE	Seedlings (0 - 1 m)	YS (>1 - 1.5 m)	MS (>1.5 - 2 m)	YT (>2 - 3 m)	MT (>3 m)
CL	205.5 ^b	2.5 ^b	602.6 ^b	83.34 ^b	55.56 ^b	24.08 ^b	35.19 ^b	12.97 ^b
RBS	827.7 ^a	9.6 ^a	2886.4 ^a	198.15 ^a	231.48 ^a	125.93 ^a	170.37 ^a	92.59 ^a
Standard error	70.01	0.76	355.21	28.99	27.99	20.07	18.08	12.57

^{ab} Means with common superscripts in the same column do not differ ($P > 0.05$)

CL: clay-loamy soil; RBS: red-brown sandu soil; TPD: total plant density; CC: Canopy cover; TTE: total tree equivalent; YS: yyoung shrubs; MS: mature shrubs; YT: young trees; MT: mature trees

Vachellia erioloba leaves harvested from clay-loamy soil areas had higher ($P < 0.05$) N content (2.42 N %) compared with those from red-brown soil areas (Table 4). *Grewia flava*, *Z. mucronata* and *S. lancea* leaves harvested from red-brown soil areas had the highest ($P < 0.05$) ADL content compared with the same species harvested from clay-loamy soil sites.

Leaves of *Searsia lancea* that were harvested from trees in red-brown soil areas had higher ($P < 0.05$) content of soluble phenolics ($714.0 \pm 2.87 \mu\text{g TAE/g DM}$) compared with those harvested in clay-loamy soil ($705.4 \pm 2.87 \mu\text{g TAE/g DM}$) (Figure 2). *Ziziphus mucronata* leaves harvested from both soil types had the lowest ($P < 0.05$) soluble phenolics values compared with all the tree species. In the clay soil, *Z. mucronata* and *S. lancea* leaves had the highest ($P < 0.05$) level of condensed tannins (Figure 3). In red-brown sand soil, *Z. mucronata* ($0.899 \pm 0.034 \text{ AU550/200 mg}$), *G. flava* ($0.860 \pm 0.034 \text{ AU550/200 mg}$) and *S. lancea* ($0.917 \pm 0.034 \text{ AU550/200 mg}$) leaves had higher ($P < 0.05$) levels of condensed tannins compared with *V. erioloba* ($0.629 \pm 0.034 \text{ AU550/200 mg}$).

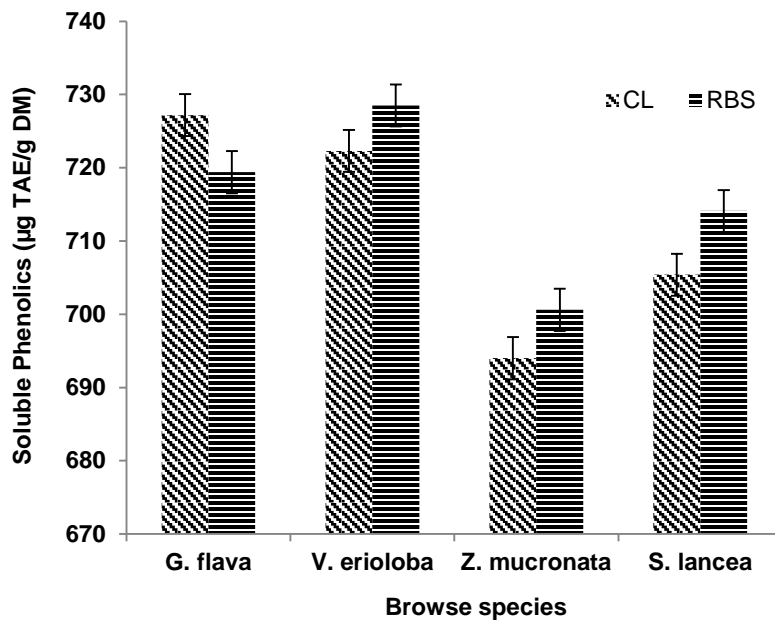


Figure 2 Soluble phenolics (µg tannic acid equivalents per g DM) of leaves from common browse species found in clay-loamy soil and red-brown sand soil types

CL: Clay-loamy soil; RBS: red-brown sandy soil

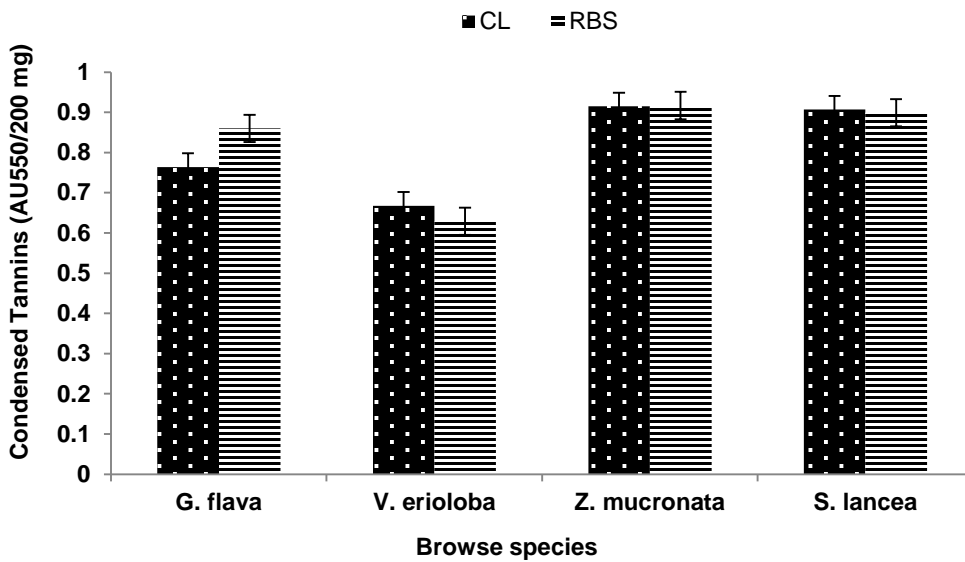


Figure 3 Condensed tannin content (AU₅₅₀/200 mg) of leaves from common browse species found in clay-loamy soil and red-brown sand soil

Table 4 Effects of soil type and tree species on chemical composition (g/kg DM, unless otherwise stated) of leaves from selected common indigenous tree species in communal rangelands located in the Loporong, Makgobistad, Six Hundred and Tsetse study sites in North West, South Africa

Tree species	DM		OM		N (%)		NDF		ADF		ADL	
	CL	RBS	CL	RBS	CL	RBS	CL	RBS	CL	RBS	CL	RBS
<i>Grewia flava</i>	918.9 ^a	914.8 ^b	858.0 ^b	850.5 ^{bc}	2.33 ^a	2.23 ^a	513.8 ^a	520.7 ^a	335.3 ^b	337.9 ^a	135.1 ^{bB}	161.1 ^{cA}
<i>Vachellia erioloba</i>	916.2 ^{abB}	929.1 ^{aA}	855.0 ^b	868.7 ^b	2.42 ^{aA}	1.99 ^{bB}	549.3 ^a	503.9 ^{ab}	416.2 ^{aA}	357.1 ^{aB}	238.7 ^{aA}	209.3 ^{bB}
<i>Searsia lancea</i>	904.1 ^b	901.7 ^c	822.5 ^c	832.6 ^c	2.38 ^a	2.40 ^a	449.9 ^b	482.9 ^{abc}	200.1 ^c	217.2 ^c	79.1 ^{cB}	101.5 ^{dA}
<i>Ziziphus mucronata</i>	920.9 ^a	926.1 ^{ab}	886.7 ^a	893.4 ^a	1.56 ^b	1.61 ^c	476.5 ^{abA}	389.3 ^{cB}	404.7 ^{aA}	312.8 ^{bB}	234.8 ^{aB}	278.4 ^{aA}
Standard error	4.14		6.11		0.07		15.62		7.62		6.41	

^{abcd} In a column, means with common lowercase superscripts do not differ ($P > 0.05$)

^{ABC} In a row, means with similar uppercase superscripts do not differ ($P > 0.05$)

DM: dry matter; OM: organic matter; N: nitrogen; NDF: neutral detergent fibre; ADF: acid detergent fibre; ADL: acid detergent lignin
CL: clay-loamy soil; RBS: red-brown sandy soil

Soil type and tree species interacted significantly to influence *in vitro* ruminal DM and N degradabilities (Table 5). In clay-loamy soil, *Z. mucronata* leaves had the highest ($P < 0.05$) *in vitro* ruminal dry matter degradability after 36 hours of incubation. In the red-brown sand soil, *Z. mucronata* (675.4 g/kg) leaves had the highest ($P < 0.05$) *in vitro* ruminal dry matter degradability after 48 hours of incubation. With regard to N degradability, *V. erioloba* (431.9 N g/kg) and *G. flava* (381.1 g/kg N) leaves harvested from red-brown sandy soil had the highest ($P < 0.05$) degradability value at 36 hours post incubation compared with all other species in the same soil type. *Grewia flava* (493.4 g/kg N) leaves harvested from red-brown sand soil had higher ($P < 0.05$) 48 h degradability value than leaves from the same species harvested in clay-loamy soil.

Table 5 Effects of species and soil type on *in vitro* ruminal dry matter (g/kg) and nitrogen degradability (g/kg) of leaves from *Vachellia erioloba*, *Grewia flava*, *Searsia lancea* and *Ziziphus mucronata* trees

Species	Incubation time (hours)							
	0		24		36		48	
	CL	RBS	CL	RBS	CL	RBS	CL	RBS
Dry matter degradability								
<i>Vachellia erioloba</i>	94.4 ^{Bb}	183.5 ^{Aa}	246.1 ^{cB}	303.7 ^{Ac}	304.1 ^{bB}	388.6 ^{aA}	303.9 ^b	368.5 ^{bc}
<i>Grewia flava</i>	105.3 ^b	129.1 ^b	287.2 ^{bc}	308.3 ^b	340.8 ^b	357.8 ^b	350.8 ^{bB}	448.0 ^{bA}
<i>Searsia lancea</i>	208.7 ^a	197.9 ^a	303.7 ^b	306.5 ^{bc}	353.6 ^b	353.2 ^b	330.6 ^b	333.2 ^c
<i>Ziziphus mucronata</i>	78.8 ^b	75.2 ^c	426.0 ^a	433.1 ^a	456.0 ^a	442.7 ^a	671.0 ^a	675.4 ^a
Standard error	17.1		15.0		26.24		31.52	
Nitrogen degradability								
<i>Vachellia erioloba</i>	156.1	183.7 ^{ab}	269.2	320.8 ^a	398.5 ^a	431.9 ^a	323.9 ^{ab}	380.8 ^a
<i>Grewia flava</i>	158.2	230.8 ^a	298.7	319.6 ^a	335.9 ^{ab}	381.1 ^a	323.8 ^{abB}	493.4 ^{aA}
<i>Searsia lancea</i>	144.6	94.4 ^b	200.7	227.5 ^{ab}	261.9 ^b	266.9 ^b	204.7 ^b	229.6 ^b
<i>Ziziphus mucronata</i>	160.5	146.6 ^{ab}	233.5	194.8 ^b	283.1 ^b	260.3 ^b	402.8 ^a	447.6 ^a
Standard error	32.4		34.9		29.7		46.2	

^{abc} Within species, means with common lowercase superscripts in the column do not differ ($P > 0.05$)

^{ABC} Within soil type, means with common uppercase superscripts in the row do not differ ($P > 0.05$)

CL: clay-loamy soil; RBS: red-brown sandy soil

Discussion

The utility of browse tree species as nutrient sources for various livestock species in communal areas has long been recognized (Aganga *et al.*, 2000). Their leaves have the potential to provide protein and energy to herbivores during extended drought (Lefroy *et al.*, 1992). Despite the obvious utility of these woody species in communal rangelands, little information about their distribution and nutritive value is available in the study area, although livestock productivity in these areas is adversely affected by seasonal feed shortages. This study, conducted in selected communal areas of North West, South Africa, explores and documents the distribution and nutritive value of these woody species across two soil types in a semi-arid climate. Intensive grazing pressure in these areas has resulted in rangeland deterioration and has created an environment that is conducive to the dominance of woody tree species to the detriment of grasses (Molelele *et al.*, 2002). The distribution of tree species was clearly influenced by soil type, with a fewer trees found in the areas with clay-loamy soil compared with those with red-brown sand soil. Clay-loamy soil has a high percentage of silt and clay-sized particles, which contribute to the higher water-holding capacity. This creates a topsoil growth environment that is more conducive to herbaceous shallow-rooted plants that can outcompete woody seedlings. The lower water-holding capacity of the red-brown sandy soil favours the deep-rooted woody plants. Species adaptation can also contribute to the variation seen in the density of tree plants. The density of *G. flava* was higher than other species in the red-brown sandy soil type. Indeed, this species is known to adapt well in rich shallow sandy soils (Mainah, 2001). The similar distribution of *Z.*

mucronata in this study across soil types could be because this species is adapted to a wide range of soils and is tolerant to a wide range of climates (Orwa *et al.*, 2009).

Woody plant density determines the productivity of available browsable material for livestock and is a useful tool in the control of bush encroachment (Smit, 1989). High density of tree plants is known to be the major cause of reduced grazing capacity of the range. Based on the density of plants per hectare, the study areas were judged to have light bush encroachment.

Different soil types possess different textures and physio-chemical properties (Quan & Liang, 2017). Areas with red-brown sandy soil had higher density of trees, seedlings, young shrubs, mature shrubs, young trees, and old trees compared with areas with clay-loamy soil. Baker *et al.* (2004) stressed that sandy soils are generally chemical poor, dominated by primary small particles that feature low structural stability and are easily eroded. Tree growth tends to be rapid on poor soil, subsequently enabling the woody species to become more densely structured (Baker *et al.*, 2004). Osman (2013) attributed soil texture to being responsible for more than 90% of tree species distribution. In this study, the red-brown sandy soil type areas had a higher percentage of CC than clay-loamy grazing areas. This might have been because the density of tree species was higher on the red-brown sandy soils compared with clay-loamy soils.

The greater abundance of tree species on the red-brown sandy soils of Loporung and Makgobistad could have prohibited the germination of grass species (Lesoli *et al.*, 2013). Only two grass species (*Aristida congesta* and *Eragrostis bicolor*) were found to be prevalent in these areas. Karuaera (2011) reported that bush encroachment is the main cause of land degradation and loss of resource productivity. Lack of competition in the veld from herbs and grass promotes bush encroachment (Jordaan & Roux, 1992). Poor soil type has also been known to contribute to the disappearance of grass species (Morgan & Connolly, 2013). Woody seedlings compete directly with grasses for topsoil resources. Poor soils can have an influence on the speed of land degradation by gradually reducing the vegetation layer in many semi-arid areas and allowing the emergence of woody species that access subsurface moisture. In addition, droughts and heavy grazing encourage the establishment of woody seedling by reducing grass cover and hence competition for nutrients (Gxasheka *et al.*, 2017).

The leaves from trees that were evaluated in this study were palatable with high nitrogen content, suggesting that they could play a vital role in livestock production as sources of protein. Leaves from *Vachellia erioloba* grown in red-brown sandy soil had higher N content compared with those harvested from areas with clay-loamy soil. Differences in soil different texture and physio-chemical properties may contribute to variation in growth, yield and chemical composition of plant species (Hossain *et al.*, 2011; Islam *et al.*, 2011). The N content for *V. erioloba* is comparable with that reported by Mnisi and Mlambo (2016). The N content in *Z. mucronata* leaves on both soil types was 2.4% DM, which is within the range (1.97 to 2.8%) reported by Hassen *et al.* (2009) and Mnisi and Mlambo (2017). Neutral detergent fibre values in this study were high (>500 g/kg DM) in *G. flava* and *V. erioloba* in both soil types. Neutral detergent fibre represents the structural carbohydrate fraction of the plant cell and includes cellulose, hemicellulose and lignin, and is known to be a reliable predictor of voluntary feed intake (Rasby & Martin, 2017). This suggests that the digestibility of these leaves could be low.

Leaves from *Ziziphus mucronata*, *V. erioloba* and *S. lancea* growing in red-brown sand soil had higher phenolics values than those harvested from trees growing in the clay-loamy soil. This consistent variation in the concentration of phenolics in this study could be attributed to the effect of soil type on the biosynthesis of phenolics. Plants growing in poor soils such as red-brown sand soil are known to accumulate higher levels of secondary plant compounds, some of which have antinutritional effects (D'Mello, 2000). These secondary metabolites function as a chemical defence, which contributes to the herbivore-avoidance mechanism of browse plants (Wessels *et al.*, 2007). In addition, high browsing pressure may induce increased biosynthesis of phenolics as part of an inductive defence mechanism (Bixenmann *et al.*, 2016). It is likely that in areas with red-brown sandy soil there is less grass cover and the woody plants are heavily browsed because they were the only feed resource available. All the browse species, regardless of harvesting site, had soluble phenolic concentration of less than 750 µg TAE/g DM, which is low and thus may not be harmful to herbivores. Filippich *et al.* (1991) and Mlambo *et al.* (2009) pointed out that high amounts of tannins (> 3 - 6%) can have a negative impact on feed intake, ruminal microbial activity and nutrient utilization by the animal.

Ziziphus mucronata leaves had the highest DM degradability of all the species at 36 and 48 hours in both soil types. This finding corroborates that by Mnisi & Mlambo (2016). Contrary to the findings on *V. erioloba* from the present study, Mabeza *et al.* (2015) reported higher degradability values after 36 hours of incubation. Low lignin in *Z. mucronata* (79 - 102 g/kg DM) compared with all other species might have been the reason for higher degradability. Lignin is a complex organic polymer that negatively affects the ability of rumen microbes to colonize and break down plant cells, thereby reducing the nutritional value of plants for herbivores. *Searsia lancea* had the lowest N degradability compared with other species after 36 hours of

incubation. The presence of secondary compounds such as tannins in this species might be a contributing factor (Moore & Jung, 2001; Mnisi & Mlambo, 2016). Tannins are known to bind to protein and other nutrients, thus reducing their availability for ruminal fermentation (Makkar, 2003). However, *Z. mucronata* leaves had higher condensed tannin content than other browse species, yet still had higher N degradability at 48 hours. This indicates that condensed tannins from different plants might have different effects on nitrogen degradability (Gemedá & Hassen, 2015) owing to differences in molecular weight and structure (Mlambo *et al.*, 2004).

Conclusion

Grewia flava and *Vachellia erioloba* were the most dominant tree species in all the sites surveyed. In both red-brown sandy and the clay-loamy soils, *Z. mucronata* and *G. flava* leaves have potential as a source of supplemental protein for ruminants. Utilization of these two species could help reduce bush encroachment while improving survival and productivity of ruminants during the dry seasons.

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Authors' Contributions

KER conducted the research as a PhD study. VM, TSB and LGP advised the student.

Conflicts of Interest Declaration

The authors declare there are no conflicts of interest

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