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Influence of seasonal variation and land management systems on soils and Colophospermum mopane forage mineral status in the central northern Namibia

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ABSTRACT

The study investigated the macro and micro-elements status of the soil and browse plants (Colophospermum mopane) between three land management systems over two seasons. Browse plant samples were randomlyharvested from five individual browse plants in each of the three nested 250 m^2 belt transects in each of the three camps per land management system. Three soil samples per 250 m^2 belt transect were collected during browse sampling at a depth of 20 cm using a soil auger. A General Linear Model (GLM) procedure of SAS (2007) was used for data analyses. The browse N level was greater ($P < 0.001$) in the ranch than the game reserve and communal in both seasons. The browse Ca level was higher ($P < 0.001$) in the game reserve than the other land management systems in winter season only. The browse Fe, Mn, Zn and Cu levels were greater ($P < 0.001$) in the ranch in winter than in summer. Soil Ca level was greater ($P < 0.001$) in winter only in the game reserve than the ranch and the communal lands. Seasonal variations in soil P was greater ($P < 0.001$) in soils collected from the ranch in winter than summer. Soil micro elements, Fe levels were greater ($P < 0.001$) in winter in the ranch, followed by the game reserve and lowest in the communal lands. Soil Zn level was higher ($P < 0.001$) in summer in the game reserve than the other land management systems. The study found that variations between land management systems and seasons greatly affected soil and browse plant minerals.

Introduction

Rangelands are the main source of livestock feed in the arid and semi-arid communal areas of Namibia. *Colophospermum mopane* (commonly known as 'mopane') is a xeric savanna woodland species that dominates vast areas of land in southern Africa, where it out-competes most other woody species within its range and generally forms mono-specific stands (Timberlake, 1995; O'Connor, 1999). Its foliage is an important browse for many herbivores. Grasses and browse plants are particularly the major sources of all essential minerals for grazing and browsing livestock, and wild ungulates throughout the year (Ngongoni et al., 2007). In many arid and semi-arid regions of Africa, poor animal growth and reproductive performance are evident even when there is adequate forage supply, which could be directly related to mineral deficiencies, resulting from low soils mineral concentrations and associated forages (McDowell, 1997). Both forage and soil mineral contents may vary depending on soil type (Ramirez et al., 2004), topography (Gizachew et al., 2002), season (Scholes and Walker, 1993; McDonald et al, 1996; Ramirez et al, 2001) and land management systems (Kgosikoma, 2011).

Livestock grazing causes disturbances to soils and this might influence savanna ecosystem productivity and fertility by altering the soil physical and chemical properties (Neff et al., 2005). In particular, these properties could be modified by livestock grazing intensity that is in turn manipulated through the practiced grazing management systems. It has been demonstrated that heavy livestock grazing pressure negatively affects soil chemical properties through increased soil compaction, soil erosion and loss (Kauffman and Kruger, 1984), decreased soil organic matter (Stephenson and Veigel, 1987), nutrient cycling and reduced water infiltration (Ingram et al., 2008). Furthermore, mineral contents of grazable and browsable forages could be affected by species composition (Tefera et al., 2009), which in turn is greatly influenced by land management practices applied. Savanna ecosystems are characterized by erratic rainfall and high rate of vegetation changes (Herlocker, 1999), soil nutrient levels (Dahdough-Guebas et al., 2002), and indications of over utilization (Skarpe, 1992). Livestock grazing and browsing management systems could exert a considerable change on the plant diversity, nutritional composition (Popolizio et al., 1994), structure and development of native plant communities (Vavra et al., 2007) in rangelands. The changes in the nutritional composition of grazable and browsable plant species in savanna ecosystems have a significant influence on the sustainability of livestock production (Sankaran et al., 2005). Seasonal variability in the mineral concentrations of native pastures and forests was similarly reported to have affected livestock production in arid and semi-arid environments (Minson, 1990).

Omusati is one of the largest regions occupied with a higher animal density and it is dominated by communal lands with limited commercial lands and game reserves. The grazing intensity of these land management systems vary greatly, with high stocking rates in the communal grazing lands, low in the commercial and medium in game reserve. In this region, no adequate studies were conducted to assess the mineral status of the browse plants and soil in response to land management systems and seasons.

Therefore, the objective of this study was to 1) determine the macro and micro-elements status of soil and the dominant browse plant species (*Colophospermum mopane*) in three land management systems over two seasons. The study focused on *Colophospermum mopane* because it is the major source of forage and nutrients in winter, particularly in the communal lands.

Materials and methods

Study area

The study was conducted in the Omusati region of Namibia, located in the central northern plain landscape at an altitude of 1095 m above sea level, and at coordinates of 17° 40′ 0′′ S and 15° 16′ 60′′ E. Omusati region is one of the 14 political regions of the country and covers about 26, 573 km^2 (Mendelsohn et al., 2000). The area has an arid to semi-arid climate with the mean minimum and maximum temperatures ranging from 20 to 37.5 °C in hot rainy season (summer) and from 7 to 27 °C in dry cold season (winter) (Kangombe, 2007). The mean annual rainfall ranges from 300 to 550 mm and occurring mostly between November and April (Mendelsohn et al., 2000). The soil in this area is generally categorised as Aerosols or Sandy soils. The vegetation is characterised by broad *Colophospermum mopane* savanna woodland, with scattered patches of the grasslands dominated by *Eragrostis* species (Mendelsohn et al., 2000).

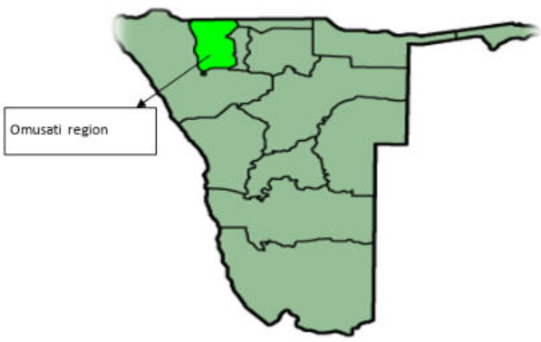

Figure 1. The location of the Omusati region in central northern Namibia

Site selection and layout

Three land management systems and grazing intensity regimes located adjacent to each other were identified for this study. These are communal land with high stocking rate and continuously grazed by livestock, government commercial ranch with low stocking rate and rotationally grazed by livestock, and game reserve with medium stocking rate and continuously utilised by game animals. The three land management systems selected were communal lands (Omaandi, Epukunoyana and Oshitutuma); the University of Namibia government ranch and Ogongo game reserve. These were the only grazing areas in the region with different land management systems and grazing intensities located in close proximity to one another. These three areas were approximately 2–5 km apart and homogenous in terms of soil, landscape and weather conditions. The communal grazing lands have been continuously grazed without well-defined boundaries and were shared by communities from adjacent villages. The grazing history of communal lands has not been well documented. However, the grazing lands had very low carrying capacity with an estimated value of 25 ha LSU^{-1}, and grazed under heavy stocking rate of approximately 3 LSU ha^{-1} for several decades.

The communal farmers raise mixed livestock species mainly of indigenous breeds. The university of Namibia government ranch had a commercial set up covering an area of about 4,550 ha that were divided into 19 paddocks and grazed rotationally.

The ranch supports Nguni (Sanga) and Bonsmara livestock breeds for beef production and small-stock, such as Boer goats and Damara sheep for over 25 years. Since recently, the carrying capacity of the ranch declined from 6–8 ha LSU^{-1} to about 10–15 ha LSU^{-1}, mainly due to recurring severe droughts and growing density of C. mopane. The current stocking rate of the ranch was estimated to be > 30 $LSUha^{-1}$. The Ogongo game reserve is located about 2 km from the commercial ranch, covering about 1000 ha and managed by the University of Namibia. The game reserve practices continuous grazing for at least the last two decades with the main production focusing on eco-tourism, conservation, venison production and students training. The current stocking rate of the game reserve was estimated to be 5 ha per mature animal (Kopij, 2013). The game animal species included five herbivore ungulates: (springbok (*Antidorcas marsupialis*), Oryx (*Oryx gazella*), plain zebra *(Equus quagga*), red hartebeest (*Alcelaphus buselaphus*) and giraffe (*Giraffa camelopardalis*)), and two main game bird species (Ostrich (*Struthio camelus*) and Guinea fowl (*Numida meleagris*)).

Three camps (served as replicates) were selected in the ranch and game reserve, with an average size of the camps estimated at 143 ha and 105 ha, respectively. In the communal areas, the three grazing lands were represented as grazing camps, with an estimated average size of 1168 ha. In each camp, three 50 m x 5 m^2 (250 m^2) belt transects were randomly marked, giving a total of 27 belt transects from the three land management systems.

Woody plant and soil sampling

For woody plant sampling, three 250 m^2 belt transects were nested in each of the three camps per land management system. Leaves and twigs were randomly harvested from five dominant individual browse plant species (*Colophospermum mopane*) in each 250 m^2 belt transect by hands. The whole area was dominated by *Colophospermum mopane* plant species. The harvested leaves and twigs samples were bulked and oven-dried at 65 °C for 48 hours. Dried samples were milled to pass through 1 mm sieve before chemical analysis. Three soil samples were collected from each of the belt transects (250 m^2) at a depth of 20 cm using a stainless steel soil auger. All soil samples were bulked and oven- dried at 105 °C for 48 hours, and milled to pass through a 2 mm sieve. Both browse plant and soil samples were collected in the wet season (summer) (March-April 2014) and dry season (winter) (August-September, 2014).

Chemical analysis

Both browse plant and soil samples were analysed for nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), iron (Fe), manganese (Mn), copper (Cu) and zinc (Zn). Nitrogen was determined by using the standard Kjeldahl method (ALASA, 1998). Plant phosphorus was analysed using ultraviolet spectrophotometer; K by flame photometer and Ca, Mg, Fe, Mn, Cu and Zn by atomic absorption spectrophotometer (Perkin–Elmer, 1982). Soil K was determined by emission spectroscopy, while Ca, Mg, Fe, Mn, Cu and Zn were determined by atomic absorption spectroscopy (Jackson, 1970).

Phosphorus was detected by ultraviolet spectrophotometer (Olsen and Sommers, 1982).

Data analysis

Both plant and soil data were analysed using a General Linear Model (GLM) procedure of SAS (2007). The macro and micro mineral concentrations were subjected to a two-way analysis of variance to test the variations between land management systems and seasons as well as their interactions. Means were compared following the PDIFF option of the least squares means statement of the GLM procedure of SAS.

Results

Browse plant macro and micro-mineral concentrations

The results on the browse plant macro and micro elements in the study areas are presented in Table 1 and 2, respectively. The browse plant samples harvested from the ranch had higher ($P < 0.001$) N level than the other land management systems in both seasons. For macro elements, the browse samples harvested from the game reserve had greater ($P < 0.001$) Ca level than the other land management systems in winter season only (Table 1). The level of P showed variations ($P < 0.05$) between land management systems in the browse samples harvested during winter only being greater ($P < 0.001$) in samples from the ranch than the other land management systems. Similarly, browse samples harvested during winter showed differences ($P < 0.05$) in K levels being lowest in samples collected from game reserves, where the Ca level was greatest.

Browse samples collected from the communal land and the ranch had the lowest Mg levels in summer and winter seasons, respectively. As for seasons, in all management systems, browse harvested during summer had greater ($P < 0.001$) N and P levels than those harvested in winter, whereas as the reverse holds true for K and Ca levels. For Mg concentration, seasonal variation was observed in forages harvested from the ranch, with the Mg concentration being higher in summer than winter season.

Land management systems also interacted significantly with seasons to influence the browse micro elements (Table 2). In summer, browse samples harvested from the ranch and game reserve had higher ($P < 0.001$) Fe levels than the communal land, but in winter, the browse samples harvested from the ranch equally had greater ($P < 0.001$) Fe level than the other land management systems. The level of Mn showed variations ($P < 0.05$)between land management systems, with the browse samples harvested during winter being greater ($P < 0.001$) in samples from the communal area and game reserve than the ranch, but in summer, the game reserve had higher Mn level than the other land management systems. Browse samples harvested during winter only showed differences ($P < 0.05$) in Cu and Zn levels, being greatest ($P < 0.001$)in samples collected from ranch and game reserves. Considering seasonal variations, in the ranch, browse samples harvested during winter had greater ($P < 0.001$) Fe, Mn, Zn and Cu levels than those harvested in summer. The browse samples harvested during winter in the game reserve and communal land did not show seasonal differences ($P > 0.05$) in Fe, Mn, Zn and Cu levels than those harvested in summer.

Table 1. Nitrogen (%), macro (%) mineral status of browse plant (mean) sampled from the three land management systems during summer and winter seasons.

	N		P		K		Ca		Mg	
Sites	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter
Game	1.5^{aB}	1.1^{bB}	0.1^{aA}	0.06^{bB}	0.7^{bA}	0.9^{aB}	1.4^{bA}	3.1^{aA}	0.3^{aA}	0.3^{aA}
Ranch	2.0^{aA}	1.5^{bA}	0.1^{aA}	0.08^{bA}	0.9^{bA}	1.2^{aA}	1.4^{bA}	1.8^{aC}	0.3^{aA}	0.2^{bB}
Com	1.4^{aB}	0.7^{bC}	0.1^{aA}	0.05^{bB}	0.8^{bA}	1.1^{aA}	1.6^{bA}	2.8^{aB}	0.2^{aB}	0.3^{aA}
SE	0.1		0.01		0.08		0.01		0.01	

Lower-case superscripts (ab) were used to compare means between seasons within each site, whereas upper-case superscripts (ABC) were used to compare site means within each season. Means with different superscripts differ significantly (P< 0.05). SE= Standard error.

Table 2. Micro (ppm) mineral status of browse plant (mean) sampled from the three land management systems during summer and winter seasons.

	Fe		Mn		Cu		Zinc	
Sites	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter
Game	41.1^{aA}	44.5^{aB}	151.7^{aA}	171.4^{aA}	5.1^{aA}	3.8^{aB}	18.6^{aA}	23.9^{aA}
Ranch	45.1^{bA}	57.3^{aA}	105.5^{aC}	120.9^{aB}	8.6^{bA}	17.0^{aA}	19.3^{bA}	27.2^{aA}
Com	31.9^{aB}	38.6^{aB}	132.6^{bB}	198.6^{aA}	3.2^{aA}	2.3^{aB}	16.9^{aA}	16.9^{aB}
SE	2.6		15.6		2.5		2.5	

Lower-case superscripts (ab) were used to compare means between seasons within each site, whereas upper-case superscripts (ABC) were used to compare site means within each season. Means with different superscripts differ significantly (P< 0.05). SE= Standard error

Soil macro and micro-mineral concentrations

Results on soil macro and micro elements in the study areas are presented in Table 3 and 4, respectively. For soil macro elements, Mg and K had similar (P > 0.05) concentrations in soils collected from all land management systems in both seasons. Soil Ca levels showed difference between land management systems in winter only being greater (P < 0.001) in the game reserve than the ranch and communal lands. Soil P levels also showed variations between land management systems in winter being higher (P < 0.001) in the ranch than the other land management systems. As for seasons, there were no significant differences (P > 0.05) in the levels of Ca and Mg between summer and winter in soil samples collected from all land management systems. The concentration of soil K differed between the two seasons in soils collected from the ranch and the communal lands, being higher (P < 0.001) in winter than summer seasons. Seasonal variations in soil P was observed in soils collected from the ranch being greater (P < 0.001) in winter than summer season. Soil micro elements, Mn and Cu had similar (P > 0.05) concentrations in soils collected from all land management systems in both seasons (Table 4). Soil Fe levels showed variations between land management systems in winter being greater (P < 0.001) in the ranch, followed by the game reserve and lowest in the communal lands.

Soil Zn also showed disparity between land management systems in summer being greater ($P < 0.001$) in the game reserve than in the ranch and communal land. Land management systems interacted significantly with seasons to influence the soils Zn level. The soil Zn concentration was higher ($P < 0.001$) in summer in the soil collected from the game reserve and the ranch than in winter season. There were no significant difference ($P > 0.05$) in the levels of Fe, Mn and Cu between summer and winter in soil samples collected from all land management systems.

Table 3. Macro (cmol kg^{-1}) elements (mean) of top soil sampled from three land management systems during summer and winter seasons.

Sites	Ca		Mg		K		P	
	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter
Game	1.6^{aA}	1.7^{aA}	0.7^{aA}	0.6^{aA}	50.3^{aA}	51.1^{aA}	4.0^{aA}	5.2^{aB}
Ranch	0.9^{aA}	1.5^{aB}	0.6^{aA}	0.7^{aA}	$38,2^{bA}$	67.0^{aA}	4.6^{bA}	7.1^{aA}
Communal	1.0^{aA}	1.5^{aB}	0.6^{aA}	0.6^{aA}	42.7^{bA}	54.1^{aA}	4.8^{aA}	5.8^{aB}
SE	0.4		0.9		7.1		0.5	

Lower-case superscripts (a, b) were used to compare means between seasons within each site, whereas upper-case superscripts (ABC) were used to compare site means within each season. Means with different superscripts differ significantly ($P< 0.05$). SE = Standard error.

Table 4. Micro (ppm) elements (mean) of top soil sampled from three land management systems during summer and winter seasons.

Sites	Fe		Mn		Cu		Zn	
	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter
Game	17.9^{aA}	17.3^{aA}	$42,3^{aA}$	$40,2^{aA}$	0.3^{aA}	0.3^{aA}	1.8^{aA}	0.2^{bA}
Ranch	16.0^{aA}	18.8^{aA}	$46,7^{aA}$	$43,5^{aA}$	0.2^{aA}	0.3^{aA}	1.1^{aB}	0.2^{bA}
Communal	14.1^{aA}	12.8^{aB}	$36,4^{aA}$	$36,6^{aA}$	0.2^{aA}	0.3^{aA}	0.5^{aC}	0.2^{aA}
SE	1.6		8.8		0.04		0.2	

Lower-case superscripts (a, b) were used to compare means between seasons within each site, whereas upper-case superscripts (ABC) were used to compare site means within each season. Means with different superscripts differ significantly ($P< 0.05$).SE = Standard error.

Discussion

Browse plant macro and micro-mineral concentrations

The greater levels of N in both seasons and P (winter) in the browse samples harvested from the ranch are more likely to be attributed to the relatively higher soil concentration of these elements in the ranch. High concentration of soil N and P may be associated with high plant litter in the ranch that might have enhanced the soil with excessive accumulation of litter throughout the year. Lowest concentration of browse K and Mg contents in samples collected from the game reserve and the ranch, respectively is difficult to explain, whereas the highest content of browse Ca from the game reserve during the winter season compared to browse samples from the ranch may reflect the soil content that was significantly highest in samples collected from the game reserve. Results on micro elements were not consistent, although the highest Fe and Cu, and lowest Mn contents were recorded in samples collected from the ranch despite the absence of variation in the concentration of these elements in the soil.

The result of this study indicates that N levels were higher in all land management systems in winter than in summer season. The greater N concentrations could be a result of a high proportion of woody debris and different removal rates of above ground biomass by grazing and browsing in the open areas (Fatunbi and Dube, 2008). The greatest Ca and K levels in the browse samples harvested in winter than in summer season could be attributed to low leaching, which enhances the uptake of Ca and K by woody plants. Low Ca levels during summer may also be the result of high or moderate availability of soil P contents (Ndebele et al. 2005), which could limit the uptake of Ca in that particular season. The findings coincide with the study of Pastrana et al. (1991) who reported low amounts of browse Ca during the wet season in the Paramo region of Colombia. Similarly, the browse Ca levels of this study were below or close to the values (15 g kg^{-1}) ascribed by the NRC (1981), as the Ca levels beyond maximum tolerable limits are widely known to reduce feed intake and, consequently, animal production performance. The lower P levels of the browse samples collected during winter than in summer season would be attributed to the high soil Ca concentration that could reduce the absorption of P by plants (Ndebele et al. 2005).

Browse samples collected in summer also had higher N content than browse samples collected in winter, which could probably be due to high soil N contents as a result of high decomposition rate of soil organic matter. Nitrogen levels of the browse leaves in the current study was in the range of 1.4% (communal) - 2.0% (ranch) during summer and between 0.7% (communal) to 1.5% (ranch) in winter season. This gives a crude protein (CP) content of 8.8-12.5% in summer and 4.4-9.4% in winter, which corroborate with the study of Tefera et al. (2009). The CP of the browse leaves collected in the summer season is adequate for maintenance and growth and therefore, could warrant consideration for use as CP supplements to poor quantity and quality herbaceous pastures that mainly occurs in the communal lands. However, browse leaves collected in winter from the communal grazing lands had insufficient CP to use as a major supplement during the critical dry period, where the forage from the grass is nearly absent. The Ca content in all browse samples was more than 1%. This is within a range that has been reported for Southern African browse species by Moleele (1998) (range: 1-2.1%) and by Tefera et al. (2009) (range: 1-2.7%) although winter samples from game reserve and communal areas had higher Ca levels. Similarly, the Mg contents of all browse samples were above the dietary requirement of 0.1-0.25% for beef cattle (National Research Council, 1996), but were below those reported by Tefera et al. (2008) for the browse species of Southern Africa. High Ca and Mg levels in the browse leaves may be due to the relative higher uptake of these elements from the soil with high content of these elements (Ca: 0-9-1.7 cmol kg^{-1} and Mg: 0.6-0.7 cmol kg^{-1}).

The K content in the soil was high, but all the browse samples collected from all land management systems had K levels below 1.5%, that is considered to be deficient from beef cattle (National Research Council, 1996). All the browse samples harvested from the three land management systems were deficient in P content in both seasons. The current study is consistent with studies of other researchers (Tefera et al., 2007; Tefera et al., 2010; Gwelo et al., 2015), who emphasised that there is ample evidence that soils in many arid and semi-arid African rangelands are deficient in P. Similarly, many researchers reported low P values for African browse plant species (Topps, 1992; Moleele, 1998; Tefera et al. 2008; Tefera and Mlambo, 2017). All browse samples collected in summer had Zn levels below the normal requirement of 20-40 ppm (National Research Council, 1996) for all livestock species, but in winter only browse samples collected from the communal lands were deficient in Zn. Zn is essential for normal plant growth and development, hence the deficiency of Zn in browse samples from the communal may affect the communal rangelands productivity and animal production. Except browse samples collected from the ranch, browse leaves were deficient in Cu levels, whereas browse samples collected from all land management systems exceeded the required levels of 20-40 ppm, but had far less than the maximum tolerable level of 2000 ppm (CSIRO, 2007).

Soil macro and micro-mineral concentrations

Soil analysis results in the study areas showed that communal land had low Ca, P and Fe contents in winter and Zn content in summer compared to the ranch or the game reserve. All the communal grazing lands were grazed at heavy stocking rates (25 ha LSU^{-1}) and therefore, high grazing pressure and the accompanying depletion of plant and litter cover, trampling and erosion are more likely to be the major causes of the decrease in the soil nutrients (Robertson et al. 1996; Snyman and du Preez, 2005; Tefera et al., 2010). However, these findings did not agree with the studies of Smet and Ward (2005) and Nsinamwa et al. (2005) who reported increased soil macro element concentrations in grazing lands subject to higher grazing pressure compared to areas with lower grazing pressure. The low soil Ca and P contents in the communal lands than the other land management systems was related to the pattern of herbaceous biomass and woody density that were far lower in the communal lands than the other land uses. Corresponding to the current indication, several studies agreed that increase in woody plant density was associated with increases in the concentrations of some soil nutrients (Thomas and Thomas, 2005; Aranibar et al., 2008). In contrast to the current results and the findings of others, Tefera et al (2007, 2008) indicated that soil elements concentration was not related to the patterns of woody plant density or cover.

The absence of significant differences in the concentration of the remaining macro elements (Mn and Cu) observed in this study was similarly reported by Tefera et al. (2007) from the semi-arid Ethiopian rangelands in Eastern Africa, who suggested that not all soil elements respond similarly to the effects of grazing pressure. Greater concentration of K and P were evident in soils collected in winter than soil samples collected in summer, but this happened to ranch/and or communal grazing lands. The greater concentration of these soil minerals might be associated with the inherent nature of savanna soils parent materials. The study indicates that the available P concentration might have accumulated in the ranch soils during winter period of slow growth, which could support the re-growth of plants in the winter season (McDowell, 1985; Tefera et al., 2007).

The higher soil K in winter could probably be attributed to stocking density (25 ha LSU^{-1}) especially in communal areas that could provide opportunity for the returning of urinary K coupled with decreased leaching of soil K in these sites. This study is in consistent with the outcomes of Gwelo et al. (2015), who also reported greater soil P concentration during winter season in the plain grazing lands of the Eastern Cape Province, South Africa and it was deemed related to greater livestock trampling on plants and defecation on the rangelands (Sinamwa et al., 2005).Similarly, the present study findings on lower soil P, particularly in summer is consistent with the findings of Jun et al. (2001) and Tefera et al. (2007) who reported that lower soil P in savanna rangelands was a common occurrence and is more likely to lead to poor animal production.Also, soil Zn concentration was found to be greater in summer than winter at ranch and the game reserve, which may be an indication that sustainable livestock production requires that the forage production is maintained or improved to provide adequate supply of forage supply throughout the year. This in turn requires a healthy soil fertility condition that supports the normal plant growth (Tefera et al., 2008). Depletion of soil fertility below a critical point could make the recovery a slow process or even irreversible (Tefera et al. 2007). The present study indicates that Ca, K, P, Fe and Mn elements were adequate for normal plant growth in soil samples from the game reserve and the ranch than communal land management system, but Mg, Cu and Zn were also deficient in soil samples from the communal areas. The finding of this study is consistent with the results of McDowell (1985) and Tiffany et al. (1998) who reported that the soil Mg and Zn deficiency results in low rangeland and animal productivity.

Conclusions

The current study indicated that different land management systems and seasons significantly impacted on the browse plant and soil minerals of rangelands in central northern Namibia. The study concluded that the crude protein of the browse plants collected from the ranch or game in the summer season is virtually adequate for the maintenance and animal growth, and could hence warrant consideration for use as CP supplements to poor quantity and quality herbaceous pastures that mainly occurs, particularly in the communal grazing lands during winter. This conclusion is derived from the results of browse leaves collected in winter from the communal grazing lands that showed insufficient level of CP to use as a major supplement during the critical dry period, where the forage from the grass is nearly absent in the area. This study also indicated that the soil in communal lands had low Ca, P and Fe contents in winter and Zn content in summer compared to the ranch or the game reserve, which showed that communal grazing lands are normally grazed at heavy stocking rates and therefore, high grazing pressure and the accompanying depletion of plant and litter cover, trampling and erosion are more likely to be the major causes of the decrease in the soil nutrients. Lastly, the study recommends for further research into the herbaceous mineral contents of the same study areas in order to provide information on the ability of the grasses to support and maintain livestock production. In addition, future studies should also research on the correlation between mineral content of the forages (grasses and browses), the soil and the body tissues of grazing and browsing animals.

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