PRELIMINARY INVESTIGATION ON PIOSPHERE FORMATION AROUND DIP-TANK AREAS IN THE LOWVELD AND LOWER MIDDLEVELD COMMUNAL GRAZING LANDS OF SWAZILAND: 1) GRASS SPECIES DISTRIBUTION AND SOIL NUTRIENTS

B. Solomon Tefera[1] and M.W. Mabuza[2]

ABSTRACT

In the communal areas of Swaziland, ticks are controlled chemically through a compulsory programme of dipping cattle and livestock movement controls. These dip-tank sites can have significant ecological effects in their surrounding ecosystems. The objectives of this study were to investigate the ecological effect of dip-tanks on the surrounding grass and soil layer in the communal grazing lands of Swaziland. Three and two dip-tank sites were selected from the Lowveld (LV) and lower Middleveld (LMV) ecological zones, respectively. At each dip-tank site, a 1000 m transect was established and divided into five sub-transects at 100 m, 300 m, 500 m, 700 m, and 900 m away from the dip-tank points to record data. A total of 20 grass species were identified in both study areas. In the LV area, notable piosphere formation includes greater frequencies (P<0.05) of Brachiaria deflexa, Bothriochloa radicans and Sporobolus africanus in the further sites, and Cynodon dactylon and Eleusine coracana in the nearest sites to the dip-tank. In the LMV area, B. deflexa, C. dactylon and E. coracana responded significantly (P<0.05) to the piosphere, generally increasing with proximity to dip-tank points, while B. radicans and

[1] Department of Animal Science, Faculty of Agriculture and Natural Resources, University of Namibia, P/Bag 13301, Windhoek. Email: teferabeyenesolomon@yahoo.com

[2] Lomahasha high school, Private Box 3, Lomahasha, Swaziland

Urochloa mosambicensis responded conversely. Generally, in both ecological zones, highly and moderately palatable groups formed piosphere with decreasing trend in moving away from the dip-tank. Most soil nutrients did not respond to the piosphere. This study concluded that the grass and soil layer are the most important components that are most sensitive to the impact of livestock around the dip-tank areas. Certainly, not all grass species and soil variables formed piosphere in response to grazing disturbance. Those variables that responded could serve as key indicators of degradation in range monitoring. The current study also recommended that if restoration of the rangelands is intended, this should focus primarily within a radius of 300 m from the dip-tanks.

Keywords: Bare patchiness, Basal cover, Lowveld, Middleveld, Palatability, Rangeland

INTRODUCTION

The rangeland of Swaziland support diverse and dynamic ecosystems which sustain crop, livestock and game farming. There are two major types of land ownership practiced in Swaziland; the Swazi Nation Land (SNL), which is held in trust by the King and is mainly for subsistence farming, and the Title Deed Land (TDL), which is free-hold and mainly for commercial production (FAO/WFP, 2002). The communal rangelands constitute a large part of the SNL. Livestock production in SNL is predominantly extensive, with virtually all cattle and small ruminants (sheep and goats) relying on communal grazing, and crop residues during the dry period.

Declining productivity of communal rangelands has been reported in many parts of Africa. In Swaziland, the major drivers of reduced productivity in the communal areas are demographic, which includes the continuous increase in human and livestock population, and decreased available grazing land as the result of the expansion of crop agriculture, private ranches and industries (Tefera *et al*., 2007a). For several decades, communal grazing lands have also been subject to alteration from their natural states by direct actions to support the traditional livestock industry. Among these alterations are the provision of artificial sources of water for livestock (Tefera *et al*., 2007b) and dipping tanks (Mabuza, 2008).

In the communal areas of Swaziland, ticks are controlled chemically through a compulsory programme of dipping cattle and livestock movement controls (FAO, 1994). The country has approximately 800 registered dip-tanks (plunge dips and spray races) at which all cattle in the communal grazing areas are mandatorily dipped at weekly intervals in summer and bi-weekly in winter. These dip-tank sites can have significant ecological effects in their surrounding rangeland ecosystems. One major effect can be focused grazing and activity patterns of the livestock around the dip-tank sites. Focused grazing activity could result in a disturbance gradient called “piosphere” which is centred on the point of references. Although various environmental impacts associated with piospheres have been documented elsewhere, there has been few studies in Swaziland that investigated whether the grazing activity around the dip-tanks could form piosphere in the distribution and composition of the grass layer as well as the soil nutrients. This study produced new information to better understand the ecological effects of dip-tanks in the Savanna ecosystems of Swaziland. Information on disturbance properties of the vegetation and soil around the dip-tank areas are vital to identify pockets of degraded rangelands that would require special management and rehabilitation measures. The objectives of this study were to assess a) the distribution and composition of grasses, and b) the status of soil nutrients along the distance gradient from dip-tanks.

MATERIALS AND METHODS

Study area

The study was conducted on SNL located in the northern part of the country. More specifically, the study areas fall in the semi-arid lower Middleveld (LMV) and Lowveld (LV) Savanna ecological zones. The LMV lies in the altitude range between 400 m – 600 m above sea level and has relatively high annual mean rainfall (625 mm – 725 mm). The LV lies in the altitude range from 250 m to < 400 m and has relatively low annual mean rainfall (400 mm – 600 mm). In both study areas, mean annual temperature varies from an average of 18^{o}C to 26 ^{o}C in summer and can fall down to 10.6 ^{o}C in winter (Remmelzwaal, 1993). These areas are mainly characterised by broad-leaved and microphyllous (Acacia) Savanna vegetation (Tefera *et al*., 2007a).

Site selection and layout

Five dip-tanks were randomly selected for this study (Figure 1). Of these, three were located in the LV, and the remaining in the adjacent LMV. Time and logistical constraints limited the number of dip-tank sites that could be studied. Dip-tanks within each ecological zone were matched as closely as possible to ensure minimum variations in terms of soil, vegetation and land form characteristics. A 1000 m transect, that began from the edge of the dip-tanks, was set out at each dip-tank. The direction of the transects was determined on the basis of what was anticipated to be the main cattle routes, evident through the density of cattle trails. Each transect was divided into five sub-transects at 100 m, 300 m, 500 m, 700 m and 900 m from the dip-tank, to represent the near (100 m), middle (300 m and 500 m) and further (700 m and 900 m) sites from the dip-tanks. In each sub-transect, a plot of 50 m x 20 m (1000 m^2) was marked to assess the herbaceous and soil layer.

Data collection

Soil sampling and analysis

Soil samples to a depth of 20 cm were collected from each plot at 10 random locations. Each set of the 10 samples was bulked, thoroughly mixed, air dried and passed through a 2 mm mesh pending analysis. Soil pH was measured in a 1:2.5 soil water relation extraction method. The Kjeldahl method was used to determine percentage total Nitrogen (N) (Van Reeuwijk, 1992). Percentage organic carbon (OC) was analysed using colorimetric method (Baker, 1976). Potassium (K) was determined using emission spectroscopy, while Magnesium (Mg), Calcium (Ca), Zinc (Zn), Copper (Cu) and Iron (Fe) were determined by atomic absorption spectroscopy (Jackson, 1970). Phosphorous was determined by the ultra violet spectrophotometer (Olsen and Sommers, 1982).

Grass species composition

Grass species composition was estimated from each 1000 m^2 plot using a step point method (Hardy and Walker, 1991). The nearest plant and basal strikes were recorded from 200 point observations per plot. When the distance of the nearest plant was farther than 40 cm from the marked step point, it was recorded as bare ground. Point observations were spaced by 2 m interval and records were made over the length of each plot in straight parallel lines about 1 m distance apart. Vegetation survey was carried out during the late growing season (February-March, 2008) when most grass species were in bloom to enhance identification.

Species identification and classification

Many grasses were identified in the field using a field guide book (Van Oudtshoorn, 1999). Those that were not identified by the researchers were taken to the National herbarium of Swaziland located at Malkern Research Station. Grasses were classified based on the succession theory described by Dyksterhuis (1949) and on ecological information for the arid to semi-arid regions of South Africa (Tainton *et al.*, 1980, Vorster, 1982). Accordingly, the species were grouped into (i) highly palatable species: those which occur in rangeland in good condition and decrease with overgrazing, (ii) moderately palatable species: those which occur in rangeland in good condition and increase with moderate overgrazing, and (iii) less palatable and poorly palatable species: those which occur rarely in rangeland in good condition and increase with severe and extreme overgrazing, respectively. In addition, species were grouped into their life forms (annuals or perennials) and abundance (dominant or common).

Statistical analysis

Data was analysed using a one-way ANOVA according to the General Linear Model (GLM) procedure of SAS (1999). The means of each distance from the dip-tank were compared following the PDIFF option of the least squares means statement of the GLM procedure of SAS. For data that did not require analysis, simple descriptive statistics was employed when necessary.

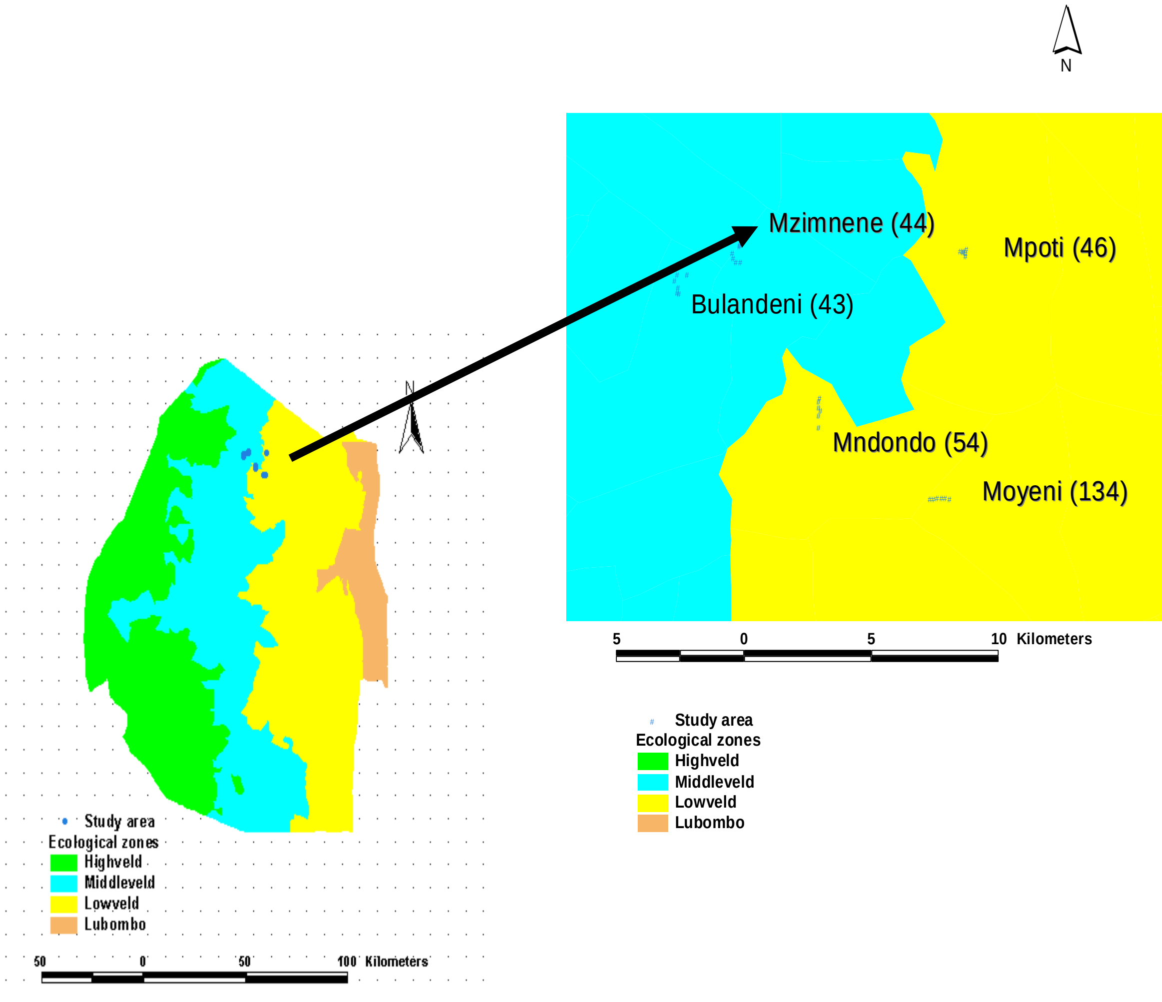


Figure 1. Map of the study sites in the northern communal grazing areas of Swaziland.

RESULTS

In both study areas, 20 grass species were identified, 45% of which were perennials. In terms of palatability grouping, 35% of the species were classified as either moderately or poorly palatable and 15% as highly or less palatable species (Table 1). In the LV area, no species was recorded as dominant or having a mean value > 15%. However, in the LMV area, *Cynodon dactylon* and

Digitaria longiflora were recorded as dominant species. *Digitaria argyrograpta*, *Panicum maximum* and *Urochloa mosambicensis* occurred as common species (mean > 5-15%) in both study areas (Table 1).

Species composition, basal cover and bare patchiness

In the LV area, significantly (P < 0.05) greater frequencies of *Brachiaria deflexa*, *Bothriocloa radicans* and *S. africanus* were recorded in the farthest sites from the dip-tank than the middle and near sites. In contrast, the proportions of C. *dactylon*, and *Eluesine coracana* showed greatest (P < 0.05) values in the sites nearest to the dip-tank (Table 2). The percentage basal cover varied significantly (P < 0.05) among the distance gradients showing a sign of declining trend with proximity to the dip-tank point. Similarly, more bare patches occurred in the nearest site being 3.3% at 100 m and 0.5% at 300 m from the dip-tank. No bare patches were recorded in the middle and farthest sites from the dip-tank (Table 2).

In the LMV area, greatest proportion of *B. deflexa* was recorded within the closer distance to the dip-tank, while greatest proportion of *B. radicans* was noticed within the farthest distance from the dip-tank (Table 3). *Cynodon dactylon* and *E. coracana* responded significantly (P < 0.05) to the gradient, generally increasing with proximity to the dip-tank point, while *Eragrostis superba* declined significantly (P < 0.05) with proximity to the dip-tank point. The frequency of *U. mosambicensis* was highest (P < 0.05) at the farthest site from the dip-tank and also showed a sign of decreasing trend in moving towards the dip-tank point. Basal cover was lower (P < 0.05) closer to the dip-tank than the middle and farther sites. Bare ground was recorded only in the nearest and middle sites from the dip-tank (Table 3).

Table 1. Life forms, palatability and occurrence of grass species in the Lowveld and Lower Middleveld of Swaziland

	Life form[a] (palatability)	**Occurence[b]**	
		Lowveld	**Middleveld**
Bothriochloa radicans	P (PP)	C	P
Brachiaria deflexa	A (MP)	C	P
Cynodon dactylon	P (MP)	C	D
Dactyloctenium aegyptium	A (MP)	+	P
Digitaria argyrograpta	P (HP)	C	C
Digitaria longiflora	A (MP)	C	D
Digitaria velutina	A (LP)	+	P
Eleusine coracana	A (PP)	P	P
Eragrostis ciliaris	A (LP)	+	P
Eragrostis cylindriflora	A (PP)	P	-
Eragrostis racemosa	A (LP)	P	P
Eragrostis superba	P (MP)	P	P
Fingerhuthia africana	A (MP)	+	+
Panicum maximum	P (HP)	C	C
Perotis patens	A (PP)	+	P
Sporobolus africanus	P (PP)	P	P
Sporobolus nitens	P (PP)	P	-
Themeda triandra	P (HP)	P	P
Tragus berteronianus	A (PP)	P	P
Urochloa mosambicensis	P (MP)	C	C

[a] A = annual, P = perennial; HP = highly palatable, MP = moderately palatable, LP = less palatable; PP =poorly palatable

[b] D= dominant (>15%), C = common (>5-15%), P = present (1-5%), + = rare ≤ 1%.

Table 2. Species composition (%) of common grass species along distance gradient from the dip-tank in the Lowveld ecological zone of Swaziland

Species	Distance from the Dip-tank (m)					
	100	300	500	700	900	SE
Brachiaria deflexa	0.01^{b}	3.2^{b}	5.67^{b}	26.8^{a}	18.5^{ab}	8.5
Bothriochloa radicans	0.01^{b}	3.67^{b}	7.33^{b}	27.8^{a}	8.1^{b}	8.9
Cynodon dactylon	28.3^{a}	7.3^{bc}	6.1^{b}	6.1^{b}	15.5^{b}	4.5
Digitaria argyrograpta	3.17^{c}	16.8^{a}	10.6^{b}	4.5^{c}	11.3^{b}	2.1
Digitaria longiflora	2.17^{b}	15.8^{a}	13.6^{a}	0.01^{b}	9.8^{a}	3.3
Eleusine coracana	23.3^{a}	0.01^{b}	0.01^{b}	0.01^{b}	0.01^{b}	5.2
Panicum maximum	12.5^{a}	11.0^{a}	12.1^{a}	8.0^{a}	10.5^{a}	3.6
Sporobolus africanus	1.5^{b}	0.0^{b}	0.01^{b}	0.6^{b}	16^{a}	1.2
Tragus berteronianus	4.5^{a}	3.3^{ab}	4.5^{a}	4.8^{a}	0.0^{b}	1.7
Urochloa mosambicensis	9.8^{a}	15.3^{a}	16.0^{a}	11.3^{a}	8.8^{a}	6.1
Basal cover	6. 0^{b}	6.3^{b}	7.0^{a}	6.3^{ab}	7.0^{a}	0.0
Bare patches	3.33	0.5	0.0	0.0	0.0	0.0

Means with different superscripts within the row differ significantly ($P < 0.05$)

Palatability groups

In the LV area, the proportion of highly palatable species differed ($P < 0.05$) greatly along distance gradient being lowest within the nearest (100 m) and further (700 m) sites from the dip-tank. Moderately palatable group displayed remarkably the greatest ($P < 0.05$) frequency at the farthest distance from the dip-tank (Table 4). The frequency of less palatable species was low (range: 0.02% - 5.7%) through the distance gradients. Significantly greatest ($P < 0.05$) proportion of poorly palatable species was noticed within the nearest (100 m) and farthest (700 m) distance from the dip-tank. Generally, highly and moderately palatable species showed a sign of decreasing trend in moving toward the dip-tank point.

Table 3. Species composition (%) of common grasses along distance gradient from the dip-tank in the lower Middleveld ecological zone of Swaziland

Species	**Distance from the Dip-tank (m)**					
	100	**300**	**500**	**700**	**900**	**SE**
Brachiaria deflexa	1.0^{b}	7.2^{a}	1.0^{b}	2.0^{b}	0.0^{b}	2.4
Bothriochloa radicans	0.01^{b}	4.2^{b}	0.01^{b}	13.0^{a}	0.01^{b}	4.1
Cynodon dactylon	37.2^{a}	12.7$^{b c}$	20.5^{b}	9.7^{bc}	5.7^{c}	5.8
Digitaria argyrograpta	6.0^{ab}	6.5^{ab}	4.2^{b}	16.2^{a}	11.7^{ab}	5.1
Digitaria longiflora	15.7^{a}	22.7^{a}	22.5^{a}	12.0^{a}	16.7^{a}	9.9
Digitaria velutina	0.01^{b}	6.7^{a}	1.5^{ab}	3.0^{ab}	0.01^{b}	3.3
Eleusine coracana	19.7^{a}	0.01^{b}	0.01^{b}	0.01^{b}	0.01^{b}	1.7
Eragrostis superba	2.3^{bc}	0.01^{c}	5.8^{ab}	7.0^{a}	9.2^{a}	2.2
Panicum maximum	4.2^{b}	14.7^{a}	7.2^{b}	10.0^{ab}	15.2^{a}	3.3
Urochloa mosambicensis	9.2^{b}	10.7^{b}	13.0^{b}	9.0^{b}	25.2^{a}	5.8
Basal cover	6.5^{b}	4.0^{c}	7.0^{a}	7.0^{a}	7.0^{a}	0.0
Bare patches	0.5	0.0	0.3	0.0	0.0	0.0

Means with different superscripts within the row differ significantly ($P < 0.05$)

In the LMV area, the proportion of highly palatable species showed decreasing trend with proximity to the dip-tank. Moderately palatable species displayed the greatest frequency (range: 42.8% – 69.0%) and generally neither remarkable difference nor clear piosphere was found. Both less and poorly palatable species exhibited no sign of response to distance gradient although the lowest and greatest ($P < 0.05$) values, respectively were recorded at the farthest distance from the dip-tank (Table 4).

Table 4. Species composition (%) based on palatability groups along distance gradient from the dip-tank in Swaziland

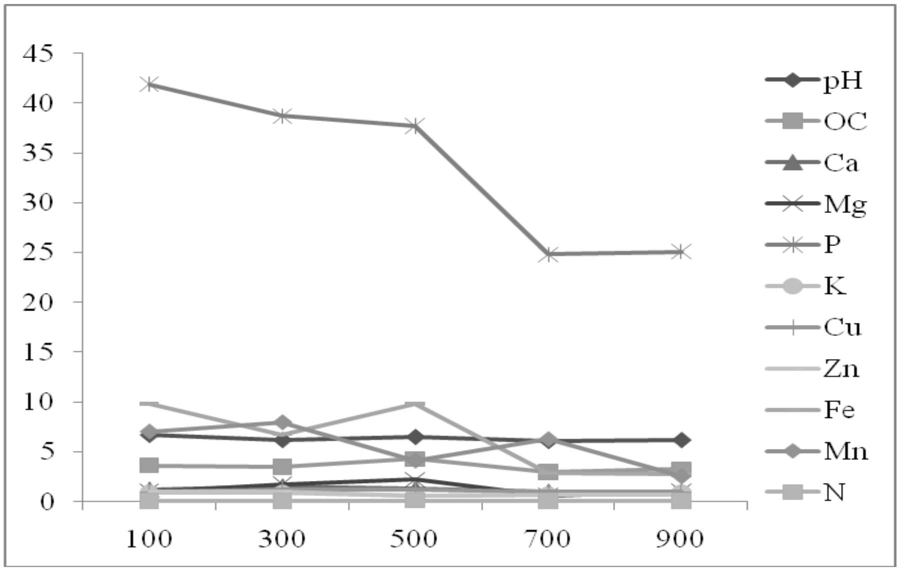
Lowveld	Distance from the Dip-tank (m)					
	100	300	500	700	900	SE
Highly palatable	16.5^{c}	32.9^{a}	32.0^{ab}	15.3^{c}	24.0^{b}	4.0
Moderately palatable	44.6^{b}	48.1^{b}	46.5^{b}	45.7^{b}	59.2^{a}	5.1
Less palatable	1.70^{b}	5.68^{a}	6.3^{a}	0.02^{b}	0.82^{b}	1.2
Poorly palatable	37.3^{a}	13.3^{b}	15.2^{b}	39.0^{a}	15.8^{b}	8.9
Lower Middleveld						
Highly palatable	10.5^{c}	21.2^{b}	13.7^{c}	30.7^{a}	27.0^{a}	2.8
Moderately palatable	69.0^{a}	63.3^{a}	64.2^{a}	42.8^{b}	64.0^{a}	9.9
Less palatable	0.02^{c}	6.2^{ab}	4.2^{b}	5.5^{ab}	9.0^{a}	2.2
Poorly palatable	20.5^{a}	9.2^{b}	17.6^{a}	20.4^{a}	0.1^{c}	2.2

Means with different superscripts within the row differ significantly ($P < 0.05$)

Soil nutrients

In the LV area, results on soil pH revealed that there was no significant ($P > 0.05$) difference and trend along the distance gradient from the dip-tank (mean: 6.3). Similarly, the levels of Ca, Mg and OC showed neither significant ($P > 0.05$) difference nor a sign of increment with proximity to or away from the dip-tank. Phosphorous decreased with increased distance from the dip-tank point. Although no marked difference was noticed, the level of N increased up to 500 m and decreased afterwards. Soil micro elements (Cu, Fe, Zn and Mn) did not significantly ($P > 0.05$) change along the distance gradient from the dip-tank (Figure 2a).

A Lowveld



B) Lower Middleveld

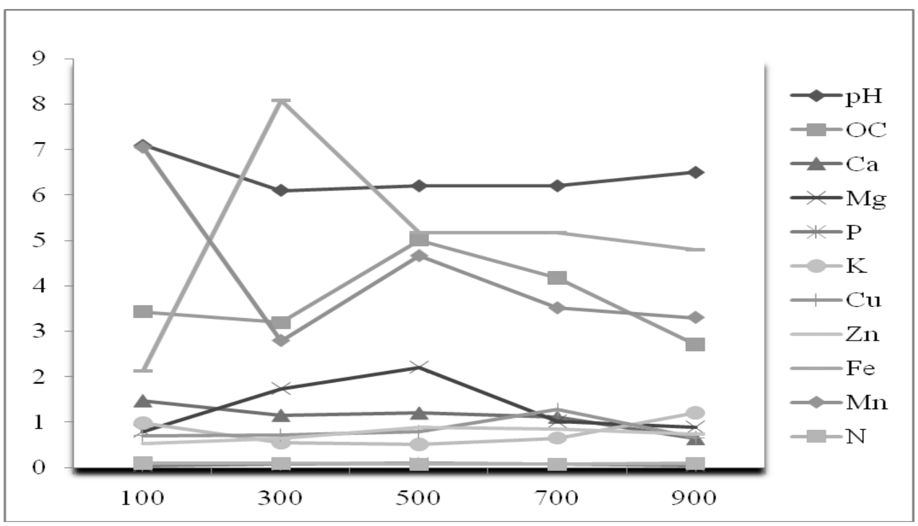


Figure 2 Variation in the mean concentration levels of soil pH, OC, macro ($cmol_c/Kg$) and microelements (ppm) along the distance gradient from dip-tank: a) Lowveld and b) Lower Middleveld of Swaziland

In the LMV area, Soil pH did not reveal significant differences along the distance gradient but indicated a slight increase in moving away from the dip-tank area. The highest (mean: 5.0) and the lowest (mean: 2.7) values of OC were measured at 500 m and 900 m from the dip-tank, respectively but overall, differences were not significant (P>0.05). Calcium content did not change greatly along the distance gradient but a decreasing trend in moving away from the dip-tank was noticed. Similarly, the level of N increased with proximity to the dip-tank points. There was no marked differences in the level of Mg, P and K, Cu an Zn along the distance gradient from the dip-tank. The highest level of Fe was recorded in sites closer (300 m) to the dip-tank. There was an indication of increasing level of Mn in moving towards the dip-tank point with the highest value (mean: 7.0) recorded within 100 m from the dip-tank (Figure 2b).

The results in this study show that except for the level of P, all soil data are noticeable for their lack of variability between the Lowveld and Lower Middleveld ecological zones (Table 5) despite their difference in the inherent diversity and nature of the parent material.

Table 5. Variation in the mean concentration levels of soil pH, OC, macro ($cmol_c$/Kg) and microelements (ppm) between the Lowveld and lower Middleveld areas

Elements	Lowveld	Middleveld	P-value
pH	6.3	6.4	0.8
Ca	1.2	1.1	0.6
Mg	1.3	1.3	0.9
K	0.8	0.8	0.8
P (mg/kg)	33.6	0.1	P<0.001
Zn	0.8	0.7	0.6
Fe	6.4	5.1	0.6
Mn	5.6	4.3	0.3

Cu	1.1	0.8	0.2
OC (%)	3.5	3.7	0.8
N (%)	0.1	0.1	0.6

DISCUSSION

Grass species identified in the current study correspond partially with those reported in the earlier studies (Tefera *et al*., 2009, Tefera *et al*., 2010). As mentioned in the previous section, the LMV area was dominated by *C. dactylon* and *D. longiflora*. These species were recorded as common (>5-15%) or present (>1-5%) in the previous study conducted in similar ecology (Tefera *et al*., 2009). Both species have been recorded as important forages for feeding ruminants in the savanna ecosystems within Africa (Tefera *et al*., 2009, Tefera *et al*., 2010). Jordan (1997) regarded *C. dactylon* as the dominant key species in overgrazed Southern Africa rangelands. The three grasses (*D. argyrograpta, P. maximum* and *U. mosambicensis*) identified as common species were rated as highly valuable species to cattle (Tefera *et al*., 2009, Tefera *et al*., 2010).

Grass species composition, basal cover and bare patchiness

The current study shows that the major changes in the LV area involves an increase in the frequency of *C. dactylon* and *E. coracana* and a reduction in the frequency of *B. deflexa*, *B. radicans* and *S. africanus* closer to the dip-tank areas. In the LMV area, while the dominant presence of *C.dactylon* and *E.coracana* prevailed closer to the dip-tank site, poorly palatable species- *B. radicans* and moderately palatable species –*E. superba* and *U. mosambicensis* were more distributed at the farthest site from the dip-tank. Based on the results of the current study, a distinct picture relating to the herbaceous species pattern or the formation of piosphere around the dip-tanks could partially emerge in both ecological zones. Similar views have been demonstrated by several studies in the semi-arid African savanna rangelands (Nsinamwa *et al*., 2005, Smet and Ward, 2005, Tefera *et al*., 2007b), but all referring to gradients around water points.

The current study concurs with previous studies (Nsinamwa *et al*., 2005, Smet and Ward, 2005) in that herbivore are no doubt the major drivers of piosphere (disturbance gradient) formation in the structure of the savanna vegetation, that was evident in the vicinity of the dip-tank area. Indeed, this process can have profound negative effect on the grazing capacity of the rangelands at large or macro level. The piosphere assumes that stocking pressure attenuates linearly with distance away from a point of reference such as dip-tank or water points, creating an almost radial pattern of impact on the vegetation. However, this study confirmed that not all grass species respond equally to the piosphere formed by grazing pressure around the dip-tank areas. For example, the distribution of *D. argyrograpta* and *P. maximum* did not respond to the piosphere in both study areas suggesting the various responses of grasses to grazing intensity. Grazing impacts which form piosphere to less or moderately palatable species could appear to be beyond the threshold levels for highly palatable species, and hence with similar effects throughout the grazing gradients.

The absence of significant effect of distance from the dip-tank areas on the frequencies of some grass species confirmed the findings of Van Rooney *et al*. (1990), and Tefera *et al*. (2007b). The study by Tefera *et al*. (2007b) associated the absence of gradient to a grazing disturbance exceeding the threshold point of grazing pressure along the complete distance gradient. Similarly, Heshmatti (2002) observed that the absence of variation in the abundance of species reflects the longer grazing history and high stocking rates which contributed to the expansion of piosphere under continuing grazing pressure for many years after the establishment of the reference points.

In both study areas, highly palatable and poorly palatable groups showed marked response to the piosphere with the former had less common distribution close to the dip-tank point where the later was greatest. This finding is not in agreement with the study of Tefera *et al*. (2007b) who demonstrated the absence of differences in the proportion of highly or less palatable species along the distance gradient from water points in eastern Africa rangelands. Additionally, in both ecological zones, distinct gradients in the amount of basal cover and bare patchiness, which are known to be good indicators of degraded rangelands (De Siyza *et al*., 2000, Smet and Ward, 2005) were found in the piospheres. In view of this, two main characteristic zones can be identified 1) 100 m - 300 m from the dip-tank having lower basal cover (mean 5.7) and high bare soil (up to 3.3%), and 2) >300 m from the dip-tank having greater basal cover (mean 7%) and low bare soil (up to 0.3%).

Soil properties

In the LV area, soil data show that Soil pH, Ca, Mg, K, OC and micro elements did not change in relation to distance from the dip-tank. However, the P level decreased with distance away from the dip-tank area. In the LMV area, soil pH, all micro and macro element did not respond significantly to the piosphere gradient although some elements (Ca, N, and Mn) showed increased levels towards the dip-tank point. This result concurred partially with the study of Tefera *et al*. (2007b) conducted in the eastern Africa rangelands. On the contrary, piosphere formation in soil properties around water points was reported in the southern Africa savanna rangelands (Nsinamwa *et al*., 2005, Smet and Ward, 2006). Centripetal movement of nutrients, herbivore grazing, trampling, defecation and urinations are mentioned as the main reasons for the gradient formation with greater concentration of nutrients closer to the water points than the further distance (Snyman, 1999, Smet and Ward, 2006). The apparent lack of piosphere formation in most soil properties in the present study is more likely associated to the minimal effect of the above attributes close to the dip-tank areas because cattle gather less frequently for dipping than for drinking.

CONCLUSION

This study investigated the ecological effect of dip-tanks in their surrounding herbaceous and soil layer. It can be concluded that in both ecological zones, a distinct picture relating to the formation of piosphere around the dip-tanks could emerge partially. In the LV area, notable piosphere formation includes greater frequencies of *B. deflexa, B. radicans* and *S. africanus* in the farther sites from the dip-tanks, and C. *dactylon* and *Eleusine coracana* in the nearest sites to the dip-tank.

The greater frequencies of *B. deflexa* and *S. africanus* in the farther sites from the dip-tank was not anticipated because the two species are poorly palatable species which increase with higher levels of grazing pressure that is evident close to the dip-tank areas. In the LMV area, *B. deflexa, C. dactylon* and *Eleusine coracana* responded significantly to the piosphere, generally increasing with proximity to water points, where the occurrence of high densities of livestock is common, while *B. radicans* and *U. mozambicensis* responded in opposite direction. Generally, highly and moderately palatable groups formed piosphere with decreasing trend in moving away from the dip-tanks areas. Basal cover and bare patchiness showed a piosphere with lower and higher values, respectively being observed closer to the dip-tanks. It can also be concluded that not all grass species and soil variables formed piosphere in response to grazing disturbance around the dip-tank areas.

Those grass species and soil variables that responded to the piosphere could serve as key indicators of vegetation degradation in range monitoring. It can be recommended from this study that if restoration of rangelands is intended, this should focus primarily within a radial symmetry of 300 m from the dip-tanks. These are the areas that showed lower frequency of highly palatable and moderately palatable groups, and basal cover and high bare patchiness. Indeed, additional studies are needed to confirm the current findings and to include more dip-tank areas, and to extend the length of the transect along the dip-tank. Research is also needed to determine how soil type, landscape and seasons affect the current results.

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