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Dynamics of Savannas in Swaziland: Encroachment of Woody Plants in Relation to Land Use and Soil Classes and Indigenous Knowledge on Plants Utilization

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Abstract: A study was conducted to assess woody vegetation pattern in the semi-arid savannas of Swaziland under three land use systems (communal land, government ranch, game reserve) and three soil classes (vertisol, lithosol and raw mineral). Communal perceptions towards the indigenous use of woody plants were also assessed. A total of 90 woody plant species were identified. Fifty eight percent of the identified woody plants have browse value to livestock. The mean density of total woody plants combined ranged between 1352 TE ha^{-1} and 11 533 TE ha^{-1}. In severely encroached area, the total woody plant density was greater ($p<0.001$) on communal land (8578 TE ha^{-1}) than in the ranch (5608 TE ha^{-1}) and game reserve (4123 TE ha^{-1}) and on raw mineral soil than lithosol. In less encroached areas, land use had no significant differences, but lithosol (2024 TE ha^{-1}) had greater density ($p<0.05$) than vertisol (1237 TE ha^{-1}). The most important encroaching species in the study areas were: *A. tortilis*, *A. nilotica*, *C. odorata*, *A. burkei*, *C. apiculatum*, *S. caffra* and *D. cinerea*. All the sites in the current study were dominated by height class of >0.05 -2 m, which suggested the potential for long-term increase. There is an indication that bush encroachment showed non to significant variations at small scale (between land uses, soil classes) and large scale levels of resolution (between study areas). At small scale level, significant variations may be due to past and present grazing pressure as well as inherent diversity and nature of the soil. This study suggests in severely encroached area in particular that generalized statements about the relatively bad condition of any land use system and the permanence of any specific condition must be treated with caution.

Key words: Browse, bush encroachment, land use systems, savannas, soil classes, Swaziland

INTRODUCTION

The savannas of Africa support large, diverse and dynamic ecosystems abundant in game, livestock and other agriculture enterprises that constitute the biggest primary production sector for many countries in the continent. Nevertheless, the productivity and long-term economic viability as well as the ecological integrity of savannas is undermined by increasingly dense thickets of woody vegetation often termed as bush encroachment.

Bush encroachment has been documented in many semi-arid rangelands in Southern Africa (Roques *et al*., 2001; Francina and Smit, 2006; Wigley, 2006). The theory of bush encroachment in savannas was presented by Walker and Noy-Meir (1982) and Noy-Meir (1982). This model described savannas as a system of two functionally separate soil layers and postulated the utilization of soil

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moisture by woody vegetation and herbaceous layer from the two distinct soil profiles. It also stated that a healthy grass layer may out-compete woody species for water in the surface soil. Therefore, a decrease in the grass layer increases moisture available for the woody plants. Cattle are responsible for opening up the grass sward and so enabling woody plant species to have access to soil moisture that could otherwise have been utilized by the grasses (Walker and Noy-Meir, 1982; Bland, 1985). Limited evidence is available on whether or not game animals are also accountable for increase in the density of woody vegetation. Bush encroachment can alter soil moisture, nutrients and micro climatic condition of rangelands and this is often accompanied by decreases in herbaceous productivity (Richter *et al*., 2001; Roques *et al*., 2001). Many studies (Epstein *et al*., 2002; Hudak *et al*., 2003; Satti *et al*., 2003) reported that woody plants also affect the distribution of soil nutrients. Overall declining conditions are symptomatic of rangelands where the ecosystems are under ecological stress in the form of bush encroachment. Encroachment of woody plants is continuously threatening the pastoral production and challenging the sustainability of livestock and game farming (Francina and Smit, 2006; Solomon *et al*., 2007a). In East Africa, an increase in bush cover by 10% reduces grazing by 7% and grazing is eliminated completely by 90% bush cover (Van Wijingaarden, 1985). In the Kalahari of Namibia, increase in bush cover reduces the pastoral industry by 75% (Adams, 1996).

Given that the savannas of Southern Africa support large and expanding human population, a loss of rangeland productivity through bush encroachment is of great significant. Therefore, the question of what determines woody encroachment is of general interest. In addressing the problem in this region, recent studies have used series of aerial photographs on rangelands with known fire history, land use practices and precipitation records (Roques *et al*., 2001; Wigley, 2006). The use of aerial photograph can be exclusively advantageous in that it covers unreachable vast areas, but this method lacks objectivity in terms of determining density, identifying noxious invaders and of determining size class distribution. Understanding of the advancement of bush encroachment, its consequences and the planning of the control measures requires quantitative data on species composition, density and height distribution classes of woody plants (Abule *et al*., 2005). Attempts were not made in the past to investigate the density and structure of woody plants in the semi-arid rangeland of Swaziland in general and taking into account the different land use practices and soil classes in particular. In addition, despite the ecological problems of bush encroachment, several woody plants have been used by the rural people for various purposes. However, the Indigenous Knowledge (IK) associated with the rich biodiversity of woody plants have not been adequately documented.

The current study was therefore undertaken to understand the effect of land use systems (communal, ranch and game reserve) on the distribution and composition of woody plants, understand the effect of soil class (vertisol, lithosol and raw mineral) on the distribution and composition of woody plants and to assess the forage and traditional values of woody plants based on the perceptions of the communal people.

MATERIALS AND METHODS

Study Area

This study was conducted in the Lowveld savannas of Swaziland. Altitude in the Lowveld ranges from 200 m to 300 m above sea level. The area has more of a semi-arid climate with mean annual rainfall ranging from 400-600 mm, while the mean annual temperature varies between 18 and 26°C (Monadjem and David, 2005). The vegetation has been classified as lowveld savanna (Acocks, 1988). Three major vegetation types were described, namely broad leaved woodland savannas, rangelands dominated by *Acacia* and the allied genera and riverine forest along the rivers and major drainage lines (Sweet and Khumalo, 1994).

Site Selection and Layout

Three land use systems: communal grazing land, government ranch and game reserve located adjacent to each other were identified in two areas locally named as Bigbend and Simunye (Fig. 1). The two areas differ mainly in the distribution of dominant soil classes and landscape features and therefore, were not considered as spatial replicates. Bigbend area is dominated by vertsiol and lithosol classes whereas raw mineral soil and lithosol represent the dominate soil classes in Simunye area. Six sites were selected, one on each of the two common soil classes for each of the three land use systems in the two areas. Three hundred meter transects were laid out randomly on each site, giving a total of 36 transects in the two areas with each area having equal number of transects. Unfortunately, there is a lack of accurate information on the grazing history of the land uses in these areas. Besides, a sequence of historical aerial photographs to document the extent of change over time was not available. However, Sweet and Khumalo (1994) and Dlamini *et al*. (2000) estimated that the stocking rate in the communal grazing land was between 2 ha LSU^{-1} and 0.94 ha LSU^{-1} before the year 2000. The government ranches represent sites with a moderate to heavy grazing pressure some years ago and the average stocking rate in recent years was estimated to be 6 ha LSU^{-1}. Similarly, the game reserves represent varied history of heavy grazing pressure with recent average stocking to be 4.4 ha LSU^{-1}.

Survey of the Woody Vegetation Layer

Three 10×10 m^2 plots (Solomon, 2003) were evenly laid out along each transect to record the variables of the woody vegetation layer. All rooted live woody plants were recorded and counted in each plot for the analysis of density, species composition and diversity. For multi-stemmed plants, an arbitrary decision was made to count the plant as a separate individual if the stems were at least 400 mm apart. Plants were recorded by species and divided into height classes of >0-0.5; >0.5-1; >1-1.5; >1.5-2; >2-3; >3-4; >4-5 and >5 m (Friedel, 1987). The plant data was then standardized to tree equivalent (1 TE = 1 shrub/ tree, 1.5 m high) for determining the total density per unit area. Indigenous knowledge and perceptions on the use of woody plants was collected from two groups of 20 communal people per group with open ended interviews. Data on vegetation and perceptions of the communal people were collected late in the growing season (March-April, 2006).

Statistical Analysis

To limit other influencing factors, the three land uses in the two study areas (Bigbend and Simunye) were chosen within a small area and this occurred only in one place in each study area. The closeness of the sites allows transects to constitute dependent representative samples of a specific soil type for the separate land uses. Therefore, field experiment in present study contained six treatment combinations with three replicates for each study area. Contrary to the design commonly applied in planned field experiment, the three transects for each treatment combination are, by necessity spatially clustered due to variations in soil and other factors over short distances.

In present study, the risk of pseudoreplication was expected because the sample area was smaller or more restricted to infer about the land use and soil effects. However, it was assumed that the errors due to pseudoreplication were lower than those associated with the non-representativeness of taking large area and those with time variables for collection of vegetation data over large sampling area. Pseudoreplication should not be considered as inappropriate as to sampling design and statistical analysis, or to the use of allowable generalization (Annika, 2000). It is often difficult to conduct ecological research at landscape level as controlled experiments and/or is costly and the problem as discussed above can seldom be avoided. Most ecological research at landscape or regional level is inferential and inductive, but conclusion drawn out need not be of less interest (Hargrove and Pickering, 1992).

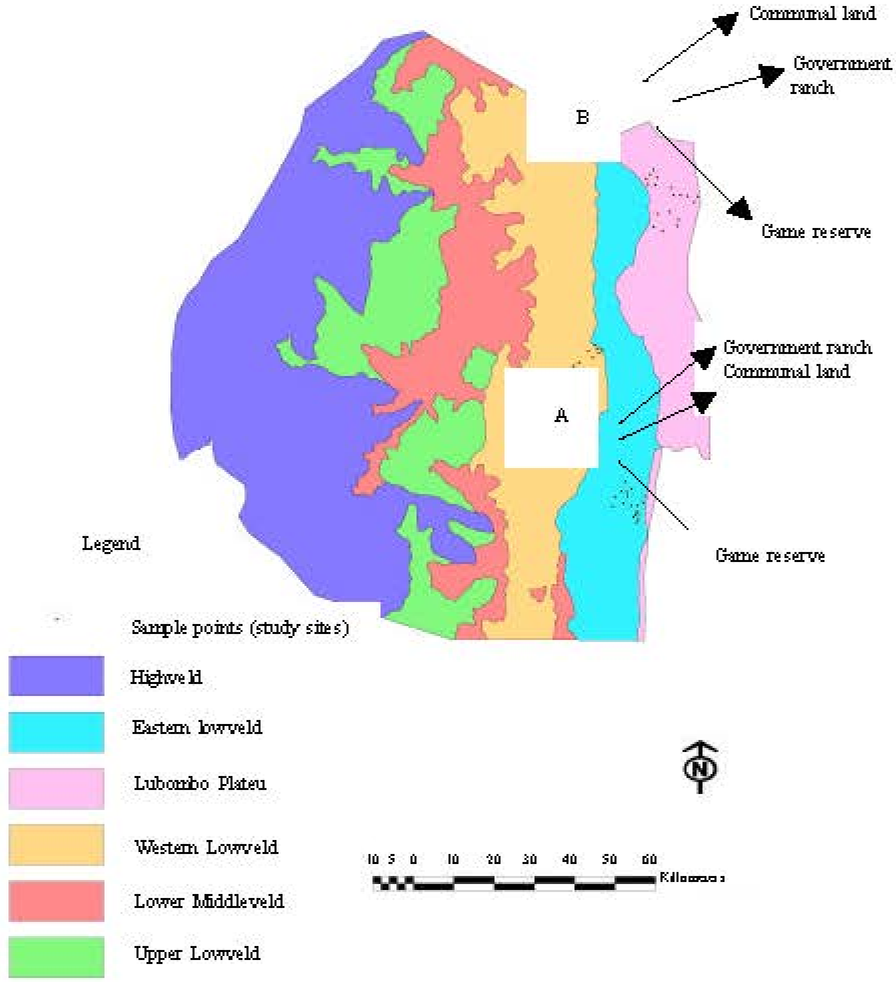

Fig. 1: Map of the study sites in the lowveld of Swaziland: Bigbend (A) and Simunyae (B). Points show the soil classes and transects under each land use system

Since data on height distribution, density and diversity of woody plants were not normally distributed and transects were few, the non-parametric Whitney U-test for two independent samples was used (Kent and Coker, 1992). The significance levels found were not compared to priori requirements, but instead used as semi qualitative 'relevance indicators' for individual differences. Shannon diversity index was employed to compute woody plant diversity for each site (Kent and Coker, 1992). For data that did not require analysis, simple descriptive statistics were employed where appropriate.

RESULTS

A total of 90 woody plant species were recorded for the two study areas of which seven were *Acacia* species as shown in Table 1.

Table 1: Scientific and vernacular name, growth form, forage and other traditional household uses of native woody plants identified in the lowveld of Swaziland

Species name	Vernacular name[1]	Growth form[2]	Feed for livestock[3] Goats	Sheep	Cattle	Major edible portion for livestock[4]	Other traditional value[5]
Acacia burkei		T	√	x	√	Leaves	Firewood; woods carved into house furniture (chair); extracts have medicinal values for breathing difficulty and chest pain.
Acacia nilotica	Sifwetfwe (inshagwe)	T	√	x	√	Leaves/pods	Fencing, poles, wood for making yoke, craving house furniture; medicinal values.
Acacia tortilis	Umsasane	T	√	x	√	Leaves/flowers	For fire woods and making roofs.
Aloe vanbalennii	Lihala	S	√	x	√	Leaves/flowers	Edible fruit for treating high blood pressure.
Dichrostachys cinerea	Lusekwane	T	√	√	√	Leaves/pods	Firewood and fencing, poles; used by royal family.
Ehretia obtusifolia	Umklele	T	√	x	√	Leaves/seeds	Edible seeds; Firewood; as medicine for cleansing stomach and curing waist; for traditional belief (bathing with it will get rid off bad luck).
Lantana camara	Bukhwebelatane	S	√	x		Leaves/seeds	Edible fruit.
Plectroniella armata	Sibhubhu	T	√	x	√	Leaves	Firewood.
Portulaca quadrifida	Emayanjane (Mnanjane?)	S	√	√	√	Leaves/seeds	Edible fruit; firewood; the seeds are fermented to produce local brew.
Aloe affinis	Lnhlaba	T	√	x		Leaves	Medicinal value for gall bladder sickness; dry leaves are used for cooking; used for poles and house construction material before roofing; dried leaf is used as a tobacco like stimulant.
Balanites maughamii	Umnovinovi	T	√	x	x	Leaves	Firewood; axes handles.
Clerodendrum glabrum	Sanhlangwe	T	√	x	√	Leaves	Firewood; medicinal value for stomach ache; for treating libido.
Erythroxylum delagoense	Umneyana	T	√	x	√	Leaves	Roots used for medicine for treating pains in the waist; for increasing libido.
Grewia bicolor	Usiphane	T	√	x	√	Leaves/seeds	Firewood, wood spears and axes, and hoes handles; edible fruits.
Lannea discolor	Singcengca	T	√	x	√	Leaves	Firewood: Used for fencing poles; the white fluid produced while it is cut is used as a stick of gum.
Maytenus heterophylla	Ingcongwane	T	√	x	x	Leaves	Firewood; woods for construction of house and as poles.
Sclerocarya caffra	Umganu	T	√	x	√	Leaves/seeds	Extracts used as medicine for chest pain; seed extracts is used for body lotion and extracts of seeds and nuts are used as cooking oil; fruits fermented for local alcoholic beverage.
Acacia gerrardii	Singa	T	√	x	x	Leaves	Woods used for house construction
Acacia xanthophloea	Umkhanyakudze	T	√	x	√	Leaves/fruits	For rituals: bark is crashed, boiled with water and bath with it believing that it gives shining in a crowd.
Berchemia zeyheri	Umneyi	T	√	√	√	Leaves/fruits	Edible fruits.
Bolusanthus speciousus	Umhhohlo	T	√	x	√	Leaves	Fire wood; Wooden poles for fencing; woods carved into house furniture; for making sticks; medicinal value for venereal diseases.

Table 1: Continued

Species name	Vernacular name[1]	Growth form[2]	Feed for livestock[3] Goats	Sheep	Cattle	Major edible portion for livestock[4]	Other traditional value[5]
Chromolaena odorata	Sandanenzwe	S	√	x	x	-	-
Combretum erythrophyllum	Ibhondvo	T	√	√	√	Leaves	Branches used for cleansing windows.
Lippia javanica		S	√	√	√	Leaves/stems	Medicinal value; twigs for toothbrush, for broom.
Matenus sp.	Sihlangu	S	√	x	x	Leaves	Medicinal value-leaf extract is used for treating diarrhoea in animals and people.
Munanthotaxis caffra	Umkholojane	T	x	x	x	-	Edible fruits; extract has medicinal value for women to treat irregular menstruation.
Ozora engleri	Infunce	T	x	x	x	-	Medicinal value-bark extract is used for treating diarrhoea in animals and people.
Solanum acanthoideum	Intfwuma	S	√	x	√	Leaves/fruits	Medicinal value-root extract is used for aching tooth and decaying gum.
Strychnos madagascariensis	Umkwakwa	T	√	x	√	Leaves	Edible fruit; Woods used for house construction.
Acacia caffra	Lugagane	S	√	√	√	Leaves	For house construction.
Bauhinia galpini	Lisololo	S	√	√	√	Leaves	Medicinal value-root extract is used for internal parasite; house construction.
Canthium ciliatum	Umuntfwamini	S/T	√	x	x		Edible fruits; house construction
Combretum apiculatum	Lindlebendlovu	T	√	√	√	Leaves	Medicinal value-leaves are used for treating flue.
Diospyros galpinii	Siphiphaban-ttwanu	S	x	x	x	-	Medicinal value for chest infection; as toilet tissue.
Elephantorrhiza elephantine	Intfolwane	T	√	√	√	Leaves	Medicinal value-leaves are used for treating flue.
Euclea natalensis		T					
Gerbera piloselloides	Mabophe	S	x	x	x		Medicinal value-the tuber for treating lower abdominal pain.
Ilex mitris	Incithamuzi	T	x	x	x	-	
Myrothamus flabellifolia	Vokwe	T	x	x	x	-	Stems are sweet and edible.
Ptaeroxylon capensis	Umtsatse	S	x	x	x	-	Medicinal value- for libido.
Strelitzia caudate	Wild banana/ ikhamanga	S	x	x	x	-	Edible fruits; used for building roofs.
Strychnos spinosa	Umhlala	T	√	√	√	Leaves/fruits	Edible fruits; Medicinal value-root is used for libido.
Trimeria trinervis	Indlebendlova						
Vernonia colorata	Linyatselo	S	x	x	x	-	Medicinal value- for stomach cure.
Ziziphus mucronata	Umphamba						

[1]= Swazi names; [2]= S-shrub, T-tree; [3,4,5] = Interview of herdsmen and communal people (n = 40)

Encroachment of woody plants in Bigbend area

Density of all woody plants combined, seedlings and small shrubs (>0-1 m) did not show differences among the land use systems (Table 2, 3). Shrubs in height class >1-1.5 m were more ($p<0.05$) common in the government ranch than game reserve, while the abundance on communal land was not apparently different from the ranch or the game reserve. Shrub density with range of >1.5-2 m height was similar to all land use systems. In contrast, large difference ($p<0.05$) was evident in height class >2-3 m, with the communal land having greatest density. Density of trees in height class >3-4 m was not affected by land use. Trees in height class >4-5 m were not recorded on communal land and in the ranch. Mature trees (>5 m) were less frequent on communal land than in the other land uses. As for soil classes, density of all woody plants combined, young shrubs (>1-1.5 m) and mature trees (>5 m) were significantly ($p<0.05$) lower on vertisol than lithosol, but other classes were remarkably

Table 2: Total density of woody plants (mean TE ha^{-1}) under three land use systems and two soil classes in Bigbend and Simunye areas

	Communal		Ranch		Game reserve	
Site	Lithosol	Vertisol	Lithosol	Vertisol	Lithosol	Vertisol
Soil[1]	(n = 9)	(n = 9)	(n = 9)	(n = 9)	(n = 9)	(n = 9)
Bigbend area	2464	930	2066	1352	1541	1427
Simunye area	Lithosol	Rawmineral	Lithosol	Rawmineral	Lithosol	Rawmineral
	(n = 6)	(n = 6)	(n = 6)	(n = 6)	(n = 6)	(n = 6)
	5623	11533	3677	4569	6661	4555

Summary

	Land use systems				Soil class		
	Communal	Ranch	Game reserve	SE	Vertisol	Lithosol	Raw mineral
Bigbend[2]	1697	1709	1484	303.70	1237^{b}	2024^{a} *	
Simunye[3]	8578^{a}	5608^{b}	4123^{b} ***	644.09		5320^{b}	6886^{a}*

[1]: n = 9 per soil class; [2]: SE-land use = 303, soil class = 428 [3]: SE-land use = 644, soil class = 525.9. *: Significant ($p<0.05$); ***: Highly significant ($p<0.001$)

Means in the same raw with different superscripts are significantly different.

Table 3: Total woody plant density (mean number of plants ha^{-1}) by height class under the land use systems and soil classes in Big bend area

	Communal		Ranch		Game reserve	
Site	Lithosol	Vertisol	Lithosol	Vertisol	Lithosol	Vertisol
Soil[1]	(n = 9)	(n = 9)	(n = 9)	(n = 9)	(n = 9)	(n = 9)
>0-0.5 m	833	100	650	3683	1333	1983
>0.5-1 m	933	217	800	383	917	700
>1-1.5 m	500	133	466	316	233	66
>1.5-2 m	350	67	183	67	33	50
>2-3 m	433	350	200	16	33	150
>3-4 m	133	83	83	50	66	116
>4-5 m	0	0	0	0	17	17
>5 m	16	0	117	17	100	17

Summary

	Land use systems				Soil class		
	Communal	Ranch	Game reserve	SE	Vertisol	Lithosol	Raw mineral
>0-0.5 m	467	2167	1658	951.3	939	1922	777.0
>0.5-1 m	575	591	808	187.3	883	433	153.0
>1-1.5 m	317^{ab}	392^{a}	150^{b}*	76.7	400^{a}	172^{b}*	63.0
>1.5-2 m	208	125	42	64.7	189	61	59.0
>2-3 m	392^{a}	108^{b}	92^{b}*	83.7	222	172	69.0
>3-4 m	108	67	92	32.9	94	83	27.0
>4-5 m	0	0	17	6.8	6	6	6.0
>5 m	8^{b}	67^{a}	58^{a}*	22.6	77^{a}	11^{b}*	18.4

*: Significant ($p<0.05$), Means in the same raw with different superscripts are significantly different

similar (Table 2). In addition, soil classes within each land use system shows a unique pattern of density and size class distribution (Table 3).

Most Common Woody Plants and Diversity

The most important encroaching species identified in Bigbend area were in descending order: *D. cinerea*, *A. burkei*, *A. tortilis*, *A. nilotica*, *E. obtisifolia* and *P. quadrifida*. *Dichrostachys cinerea* was more common on communal land than in the ranch and game reserve. *Acacia burkei* and *P. quadrifida* were more abundant in the ranch (Table 4). For *E. obtisifolia*, a significantly lowest density was

Table 4: Density of common woody plant species (mean TE ha^{-1}) in relation to the land use systems and soil classes in the two study areas

	Bigbend area						
	Land management systems				Soil classes		
Species	Communal land	Government ranch	Game reserve	SE	Lithosol	Vertisol	SE
Acacia bureki	118^{b}	412^{a}	13^{b*}	92.00	352^{a}	10^{b}	75.00
Acacia nolitica	54	66	100	43.30	63	84	35.30
Acacia tortilis	198	87	100	41.10	106	151	33.50
Dichrostachys cinerea	857^{a}	270^{b}	247^{b*}	189.00	521	394	154.00
Ehretia obtisifolia	3^{b}	110^{a}	162^{a***}	23.31	76	112	19.00
Portulaca quadrifida	-	64^{a}	2^{b***}	9.53	31	13	7.78
	Simunye area						
	Communal land	Government ranch	Game reserve	SE	Lithosol	Raw mineral	SE
Acacia bureki	643a	-	19^{b}	39.1	200	241	39.9
Chromolaena odorata	296^{b}	93^{c}	785^{a}	271.6	504	545	221.7
Combretum apiculatum	744^{a}	397^{b}	-	204.8	546	214	167.2
Dichrostachys cinerea	1041^{b}	1545^{a}	586^{b}	148.9	1188	927	121.6
Sclerocarya caffra	373^{a}	92^{b}	-	90.6	167	144	74.0

*= Significant ($P < 0.05$); **/*** = Highly significant ($p<0.01/0.001$)

Means in the same raw with different superscripts are significantly different.

Table 5: Total woody plant density (mean number of plants ha^{-1}) by height class under the land use systems and soil classes in Simunye area

Site	Communal		Ranch		Game reserve	
Soil[1]	Lithosol (n = 6)	Vertisol (n = 9)	Lithosol (n = 6)	Vertisol (n = 6)	Lithosol (n = 6)	Vertisol (n = 6)
>0-0.5 m	917	867	400	767	967	600
>0.5-1 m	783	866	733	667	1350	752
>1-1.5 m	1533	1466	550	217	683	533
>1.5-2 m	733	1033	483	317	400	750
>2-3 m	618	1100	817	333	400	617
>3-4 m	33	300	616	483	167	250
>4-5 m	0	267	333	50	67	0
>5 m	583	1417	382	467	150	317

	Summary						
	Land use systems				Soil class		
	Communal	Ranch	Game reserve	SE	Vertisol	Lithosol	Raw mineral
>0-0.5 m	891	583	783	249.60	761	744	203.8
>0.5-1 m	825	700	1050	219.90	955	761	179.5
>1-1.5 m	1500^{a}	383^{b}	608^{b***}	118.30	922	738	167.4
>1.5-2 m	883^{a}	400^{b}	575^{b*}	98.70	538	700	80.6
>2-3 m	858^{a}	575^{b}	508^{b*}	96.20	611	683	78.6
>3-4 m	166^{b}	550^{a}	208^{b**}	76.90	272	344	62.8
>4-5 m	133^{a}	191^{a}	33^{b**}	30.00	133	105	24.5
>5 m	1000^{a}	425^{b}	233^{b***}	92.29	372^{b}	733^{a*}	75.3

*: Significant at $p<0.05$; **/*** = Highly significant ($p<0.01/0.001$). Means in the same raw with different superscripts are significantly different

obtained on communal land. The density of *A. tortilis* and *A. nilotica* was not significantly affected by land use. As regards to soil classes, the most striking difference was obtained only for *A. burkei*.

Shannon's diversity was significantly greater in the ranch than the other land uses. There were more diverse plants on lithosol than vertisol (Fig. 2). It was observed that 24% of the total woody plants were common to the three land use systems, 6% to the communal and the ranch, 18% to the

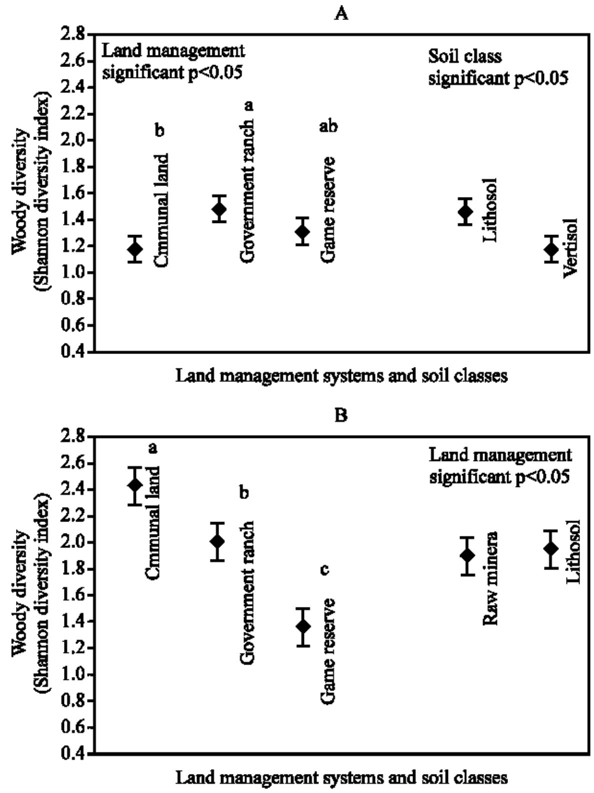

Fig. 2: Woody plant diversity index in the three land management systems and two soil classes in Bigbend (A) and Simunyae (B) area

communal and game, 15% to the ranch and game reserve. The percentage of woody plants common to any of the land use system varies between 9 to 18%. As for the soil classes, 50% of the woody plants were common to the two soil classes and 26% to only the lithosol soil.

Encroachment of Woody Plants in Simunye Area

Total density for all woody plants combined differed significantly among the land use systems. This was greater on communal land, followed by government ranch (Table 2). The density of seedlings (>0-0.5 m) and young shrubs (>0.5-1 m) did not show marked difference among the land use systems. There were more shrubs (>1-2 m) and trees (>2-3 m) on communal land than in the other land use systems. For trees >3-4 m height, the communal land and game reserve had similar and significantly lower densities than the ranch. There were more trees (>4 m) on communal land than in the other land use systems. As regards to soil classes the density of all woody plant combined was greater ($p<0.05$) on raw mineral than lithosol. However, soil classes within each land use showed a different pattern of variation. Inconsistent results were found for size class distribution between soil classes within each land use, but in general, except for mature trees above 5 m, significant differences were not evident between lithosol and raw mineral soil (Table 5).

Most Common Woody Plants and Diversity

Among the common woody plants identified in Simunye area, the most important encroaching species in descending order were *D. cinerea*, *C. odorata*, *C. apiculatum*, *A. burkei* and *S. caffra*.

Dichrostachys cinerea was more abundant in the ranch than on communal land and game reserve. Encroachment of *C. odorata* was more severe in the game reserve, followed by communal land (Table 4). *Combretum apiculatum* and *S. caffra* were not recorded in the game reserve, but the communal land had nearly two and three times the TE density in the ranch, respectively. *Acacia burkei* was more common on communal land than in the game reserve.

Shannon's diversity index values revealed that communal land had the richest plant diversity where as the game reserve had the lowest. As for the soil classes, diversity on lithosol and raw mineral soil was similar (Fig. 2). Seven percent of the total wood plants identified were common to the three land use systems, 12% to communal and the ranch, 13% to communal and game, 4% to the ranch and game reserve. Thirty-three percent of the total woody plants was found only on communal land, 29% in the ranch and 8% in the game reserve. Results for the soil classes indicated that 30% of the total woody plants were common to the two soil classes while the lithosol had 36.

Common Use of Woody Plants

Opinions of the communal people indicated that 58% of the total woody plants identified has forage values to livestock. Twenty-one percent was used by the three livestock species, 39% by goats and cattle and 35% browsed by goats. Leaves are the major edible portion of most browse plants followed by the seeds. The role of woody plants in other traditional uses was also discussed (Table 1). The result showed that 87% of the total plants had traditional values in addition to the role as browse plants. These include fencing and firewood (24 species), house construction (11 species), making house utensils and furniture (12 species), traditional medicine for people and livestock (41 species), human food (17 species), rituals (5 species) and local beverages and body lotions (3 species).

DISCUSSION

Total Density and Diversity

The overall mean total woody plant density in the lowveld savanna of Swaziland ranged from 1352 TE ha^{-1} to 11533 TE ha^{-1} which indicates the existence of great variability at site and landscape level of resolution. Comparison of the two study areas explained that bush encroachment is a more serious problem in Simunye than Bigbend area. Woody plant density of 2400 ha^{-1} was regarded as borderline between non-encroached and encroached condition in African Savannas (Roques *et al*., 2001). A density of 2500 TE ha^{-1} was considered as highly encroached condition in Southern Africa (Richter *et al*., 2001). Based on these results the lowved of Swaziland is in a state of light to severely encroached condition. Advancement of bush encroachment has been reported in many semi-arid regions of Southern Africa. Hudak and Wessman (2001) reported a 30% increase in woody plant cover between 1955 and 1996 for Madikwe Game reserve, South Africa. Roques *et al*. (2001) investigated that woody plant encroachment increased from approximately 3% to over 40% in 50 year in South African communal rangelands.

In the less encroached area (Bigbend), difference in soil class was more important than land use to cause variation in total woody plant density. In severely encroached rangelands (Simunye area) however, total density differed significantly among the land use systems and between soil classes. The current findings agreed with Smet and Ward (2005), who reported that shrub encroachment on communal land was more severe than in the other land use systems in the North Cape of South Africa which is also supported by a study conducted in the North-district of Botswana (Annika, 2000). In contrast, substantial increase in bushes for the three land use systems were reported in Hluhluwe area in Kwazulu-Natal of South Africa, with the communal land-the least severely affected (Wigley, 2006). The study of Solomon (2003) in East Africa rangelands had indicated that the magnitude of bush encroachment was not significantly related to land use practices.

In the current study, the communal land in a severely encroached area is characterized by an increasingly consistent heavy grazing pressure. Sweet and Khumalo (1994) and Dlamini *et al*. (2000) estimated that the stocking rate in the lowveld was between 2 and 0.94 ha LSU^{-1} before the year 2000. Although an estimate of the recent stocking rate is unavailable, improvement is not expected because of increased external forces that could reduce available grazing area (Solomon *et al*., 2007a,b, unpublished). The government ranch represents an area with a history of heavy grazing pressure some years ago and hence severe bush encroachment occurred. Recently, the stocking rate at the ranch was significantly reduced (perhaps due to the invasion of the ranch by *C. odorata*). Similarly, the game reserve was observed as an area with a history of heavy grazing pressure. Prior to its establishment (before 1986), the game reserve was utilized as cattle ranches with average estimated stocking rate of 4.4 ha LSU^{-1}, but has only been sparsely populated in recent time. Since differences in land use are often linked to differences in stocking rate/land management practices, it is difficult to separate the effect of one from the other (Parsons *et al*., 1997). The high cattle densities commonly practiced in the communal area of Southern Africa were reported to be the main cause of bush encroachment (Skarpe, 1986; Ringrose *et al*., 1996). High grazing pressure may be a key determinant of shrub encroachment through grass fuel removal and concomitant reduction in fire frequency. On the other hand, lower fire frequency promotes woody plant recruitment and in the long run, may lead to shrub encroachment (Van Auken, 2000). Results obtained in the southern rangelands of Ethiopia suggested that external factors such as cultivation and land alienation inappropriate to the communal grazing systems compressed the available grazing land and changed spatial pattern of land use (Oba *et al*., 2000; Solomon *et al*., 2007a). Consequently, this will increase the grazing pressure on the remaining grazing land which will contribute to the advancement of bush encroachment. Some works in other parts of Southern Africa do not support the theory that high cattle densities are the main driving factors (Abel, 1992).

It is important to note that problems of scale could emerge when trying to correlate bush encroachment with land use systems. Results from grass-tree plot scale experiments within a small patch of savannas may contradict results of broad scale studies. Gosz and Sharpe (1989) and Anthony *et al*. (2006) noted that large scale vegetation pattern could be correlate with climatic (mainly rainfall) and other geographical variables. In addition, variations at small scale can occur due to site-specific characteristics other than land use such as soil discontinuities and proportions. Belsky (1990) noted that patchness of rainfall at small scale could occur and this may lead to patchy woody vegetation patterns but within a range of intermediate long-term rainfall levels only.

When comparing the soil classes in present study, heavier encroachment was noted on lithosol and raw mineral soil than vertisol. The former soils are characterized by a shallow layer of sandier soil (5-35 cm) compared to the later (>60 cm). Therefore, rooting niche separation may not be a prerequisite for woody plant encroachment because encroachment may occur on soils too shallow to allow for root separation (Wiegand *et al*., 2006). In contrast, Walker and Noy-Meir (1982) and Noy-Meir (1982) explained that savanna is a two layered soil water system in which the roots of woody plants and grasses are confined to separate soil layers. Booth and Barker (1981) contended that susceptibility of soils to bush encroachment increases as the soil becomes sandier while the texture which determines the hydrological functioning in turn affects the redistributed water use by the plants.

Indeed, the overall increase in woody plants in the study areas could be due to the introduction of plants into new areas and/or the gradual thickening of the existing vegetation. Ruminants may act as a dispersing agent by browsing certain woody plants (Radford *et al*., 2001; Tews *et al*., 2004) and their fruits and later disperse the encroacher seeds via the dung (Solomon, 2003). Some invasive shrubs that produce copious number of viable seeds can be dispersed by other agents such as wind, birds and water.

Woody plant diversity in present study showed a clear but non-consistent difference in relation to land use systems, whereas the difference in relation to soil classes was not apparent. Furthermore, this study portrayed that the communal land had the most diverse and rich species in severely encroached area which is in contrast with the published data of Smet and Ward (2005) who reported that the commercial ranch had more diverse and richer species composition than the other land use systems.

Densities and Proportional Distribution of Height Classes

All the sites in the study areas were dominated by shrubs (>0.5 -2 m) with an average of 44%. However, overall patterns of height class distributions differ between land use systems and soil classes. Mature trees (> 5 m) were recorded from very few in low density area to very high in severely encroached area. The dominance of small shrubs in encroached rangelands was reported in many savanna rangelands in Africa (Van Vegeten, 1981, Friedel, 1985; Solomon *et al*., 2007a). Three theories can explain the dominance of small, low growing plants in the current study (1) could be a result of genotypes with stunted growth and short life span (Van Vegeten, 1981) as reflected in the total woody plants identified in the present study to be 26% being shrub growth forms; (2) the age of the plant and (3) the consequence of spatial and temporal pattern of competition for water and nutrients between closely spaced woody plants (Solomon, 2003). The higher densities of woody plants in the height class >0.5-2 m could be an indication of the potential for long-term increase. However, smaller size classes are effectively controlled by burning provided there is enough grass fuel load to burn the bushes (Solomon, 2003). Regardless of growth forms, height class represents the age of the plant and its pattern of distribution explains different stages of invasion. Therefore, control of bush encroachment may require a thorough understanding of the different growth stages and the life cycle of the plant.

Common Woody Plants

Many encroaching woody plants identified in present study showed variability in total density at landscape level of resolution. *E. obtisifolia*, *P. quadrifida* and *C. odorata* were not documented in the previous report (Dlamini and Rycroft, 1981). The population of *C. odorata* was restricted to study sites in Simunye area, but patches of *C. odorata* were visually observed outside the study areas. The invasion of savannas by *C. odorata* is a recent phenomenon with episodic potential threat to livestock, game and crop farming as well as the biodiversity conservation in the region.

The present study indicated that *A. burkei* and *D. cinerea* may grow on a variety of soil types, but showed preference to sandier soils especially on the raw mineral and lithosol soil. Many encroaching species showed significant differences between the land use systems though without overall consistent trend. *Acacia burkei*, *C. apiculatum*, *S. caffra* and *D. cinerea* showed the greatest density on communal land. The result implied that the four species are good indicators of disturbance gradient for rangelands subject to long-term over utilization. Although *C. apiculatum* and *D. cinerea* were reported to be the commonest encroaching species in Southern Africa rangelands (De Klerk (undated); Annika, 2000), their abundance was not significantly related to land use practices. In any case *A. tortilis* was shown as one of the encroaching species in east Africa rangelands (Solomon, 2003).

Common Use of Woody Plants

The current study which indicates, that forage utilization of woody plants accounted for the highest contribution agrees with Gemedo *et al*. (2005) and Solomon *et al*. (2007b). The woody plants of forage value and not mentioned in earlier study (Dlamini and Rycroft, 1981) were: *E. obtusifolia*, *P. quadrifida*, unidentified species locally named as *Yaweyawe*, *Ingogola*, *Umlahlantfwana*, *Ndlebetendlovu* and *Sinukane*. Woody plants browsed by three livestock species included *D. cinerea*, *P. quadrifida*, *L. javanica*, *B. zeyheri*, *C. erythruphyllum*, *B. galpini*, *S. spinosa* and *C. apiculatum*. The foliage of woody browse and leaf succulent plants appeared to be an important food resource for goats particularly where the availability of forbs is limited (Hendricks *et al*., 2002). Empirical evidence in Southern Africa suggested that, cattle diets showed significant fraction of browse with an annual mean of 20% (Fritz *et al*., 1996). The current study also ranked medicinal value of woody plants next to forage utilization. In contrast, medicinal value is the largest plant use for most of the rural people in South America (Coe and Anderson, 1999; Rossato *et al*., 1999). In East Africa, Solomon *et al*. (2007b) ranked medicinal value next to forage and food utilization. Therefore, plants used for this purpose may play critical role in the development of sustainable health practices.

Wild edible plants constitute 19% of the total species in the present study and were given a fourth rank. *Ziziphys*, *Euclea*, *Lantana* and *Sclerocarya* species were similarly reported as edible plants elsewhere in Africa (Gemedo-Dalle *et al*., 2005; Solomon *et al*., 2007b). Nutritional analysis of a few wild plants in the Sahel revealed protein, vitamin and mineral contents to be comparable to the WHO standards (FAO, 1986).

CONCLUSIONS

This study concludes that bush encroachment showed non-to-significant variations at small scale level between land use systems and soil classes. Great variability at large scale level was also evident. At small scale level significant differences between the land use systems occurred in severely encroached area and past as well as present grazing pressure could be the major attributing factors to promote bush encroachment and cause differences between the land uses. This is particularly the case where the communal grazing land had more encroachment and the other land use systems manifested lower densities but beyond a threshold condition. Differences between soil classes were due to their inherent diversity and nature. The present study suggests in particular that generalized statements about the relatively bad condition of any land use system and the permanence of any specific condition must be treated with caution. External factors such as expansion of cultivation and land alienation inappropriate to the communal grazing may be added factors to indirectly promote encroachment of woody plants, but scientific examination to validate this theory requires long-term investigation. Furthermore, the most abundant size classes of wood plants (>0.5-2 m) are within the range vulnerable to fire, but also a sign of lasting increase. In general, although bush encroachment is a slow process which limits the present study, future investigation must confirm the findings and be expanded to include various soil types, landscape and rainfall patterns. Woody plants identified as browse and medicinal require research attention as forage and pharmaceutical resources while nutritional assessment and other indigenous knowledge of the wild plants consumed by the rural people remain essentially imperative.

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