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SOIL DEGRADATION FOLLOWING LAND USE AND COVER CHANGE IN THE RANGELANDS OF UGANDA

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ABSTRACT
A modified-Whittaker sampling design was used to collect soil samples in three land cover types (bare, herbaceous and woody) under three production systems (settled, semi-settled and non-settled) and analyzed for selected chemical (pH, OC, OM, N, Ca, Mg, K, Na, CEC and available Phosphorus) and physical (bulk density, porosity, conductivity, structure and texture) properties. Analysis of variance, discriminant analysis and principle component analysis were conducted using XL-Stat software. Soils from bare land under non-settled production systems had significantly high levels of clay ($p<0.0001$) and bulk density ($p<0.02$) and significantly lower levels of sand ($p<0.04$) and porosity ($p<0.001$). Herbaceous vegetation had significantly high levels of organic matter and total nitrogen ($p < 0.001$) compared to woody and bare soils, while woody had significantly high levels of available P ($p < 0.04$). The semi-settled production systems had high levels of pH ($p < 0.04$), Ca ($p < 0.038$) and CEC ($p < 0.001$) compared to the settled and non-settled systems. Herbaceous vegetation under the semi-settled production system had significantly high levels of organic matter ($p<0.004$), total nitrogen ($p<0.003$) and Ca ($p<0.028$) compared to other land use and cover types. Soil properties of bare and woody cover are slightly similar (5.6%) while a great similarity exists between woody and herbaceous cover (72%). The distinctiveness of bare from herbaceous cover indicates that grazing areas have been degraded to levels below their recuperative capacity and therefore rehabilitation back to herbaceous cover requires more time and external investments other than resting alone.

KEY WORDS: Grasslands, Nakasongola, Production system, Rehabilitation, soil quality

INTRODUCTION

The increasing pressure exerted on land resources is driving major land use and land cover changes in the rangelands of Uganda and consequently leading to a reduction in the quantity and quality of services they provide. The rangelands of Uganda are well known as the cheapest source of food for livestock production that sustain more than 90% of the ruminant population and supply more than 85% of the total milk and meat in the country (Kisamba-Mugerwa, 2006). Grazing is therefore a major rangeland product on which pastoral livelihoods revolve. However, the escalating changes in land use and land cover that lead to a reduction in grasslands are posing a great threat to the sustainability of rangeland ecosystem, livestock production, food security and livelihoods of rangeland inhabitants. The most conspicuous land cover change in the grasslands of Uganda is the wide spread encroachment by woody species and bare ground which have affected more than 50% of the grazing land in Nakasongola district with an annual encroachment rate of 15% (Zziwa, 2011).

Bare and woody encroachment on grassland is often associated with major changes in soil cover, soil erosion, and affects several physical, chemical and biological properties of soil and biodiversity (Andrieu *et al.,* 2007; Seabrook *et al.,* 2007). Because of the present and envisaged detrimental impacts of land use and cover change on ecosystem products and services and their threat on livelihoods, rangeland inhabitants are attempting several management practices to adapt to the imposed consequences. However, in a bid to adapt, land cover changes have been accelerated in some areas while in others unexpected and undesirable feedbacks have been initiated that drive more changes and continue to compromise the grassland ecosystem. Because the soils in most rangeland communities of Uganda have a limited production potential (Radwanski, 1960; Langdale-Brown *et al*., 1964) land use and cover changes might have immense impacts on soil properties and impart challenges on rangeland restoration processes since alleviation of suspected causes of degradation does not take the system to its original state. More to that, high level management practices that involved reseeding of degraded rangelands failed because the soils could no longer support plant growth (Mugerwa et al., 2008). Land use and land cover change have also compromised the resilience of rangelands to climatic variability and change as some ecosystems are so much altered that a slight perturbation in climate makes them fail to return to their original states. The adaptive capacities of pastoral communities to the effects of climate variability and change are increasingly lowered thus making them more vulnerable to food insecurity and poverty.

The high dependence on land resources for subsistence posses a growing threat for widespread natural resource degradation (Rohit *et al*., 2006). The extensive degradation of soils and reduction in biodiversity following the conversion of natural land cover systems and implementation of different land use practices is greatly impacting on the sustainability of agricultural production systems throughout the world. The rangelands of Uganda are regarded as severely degraded land forms (NEMA, 2006; 2008). This degradation is believed to be associated with changes in soil chemical and physical properties as reflected in increasing crop failures and low pasture production. However, the only existing information on classifications of soils in Uganda and their potential productivity levels were conducted over sixty years back (Radwanski, 1960; Langdale-Brown *et al*., 1964). Given the increasing changes in land use as a result of increased population pressure and changes in management system, there is a growing need to assess the chemical and physical properties of soil in these areas so as to understand their production potentials and devise informed management practices for rehabilitation of degraded soil resources in the rangelands of Uganda. In study, selected physical and chemical properties of soil were analysed from bare, woody and herbaceous cover and were then used to assess whether the alien land cover types in grasslands had significantly changed the soil properties.

MATERIALS AND METHODS

Study area

The study was conducted in Nakasongola district, covering two sub counties of Nabiswera and Nakitoma. The study area was characterized into three production (land use) systems (settled, semi-settled and non-settled) which were stratified into three land cover types (herbaceous, woody and bare) in which six locations were randomly selected for establishment of the sampling sites.

Description of production systems

Settled: These include areas where the rangeland was individualized, fenced and planned rotational grazing is practiced. There are high investments in these production systems for water development and fencing of paddocks and there is limited or no migration even in dry seasons. Because of the high investment costs incurred, producers often strive to obtain more profits and hence tend to have high stocking rates on well managed paddocks and water resources.

Semi-settled: These include areas under private and communal property rights. In this case, the individual or community has the right to exclude others from using the resource and regulate its use. However, there is limited fencing and control of stock movement over the land. In some areas only perimeter fencing is provided but there is no planned rotational grazing (no paddocks) and they are also characterized with stock movement from one area to another during dry periods (sedentary pastoralism and transhumance are still practiced in these areas).

Non-settled: These are systems where exclusion or control of access of potential users is problematic. There is no fencing (neither perimeter nor paddocks) and thus controlling access of potential users is virtually impossible. There is therefore open access making land a common property and its continued use involves subtractability (Berkes et al., 1989). In the non-settled systems, land is subjected to unknown and uncontrolled numbers of livestock where each herder intends to maximize the use of resources thus leading to resource degradation, the tragedy of the commons (Hardin, 1968).

Sampling procedure

A Modified-Whittaker plot measuring 20 m × 50 m (Figure 2) was placed with the long axis parallel to the environmental gradient (Stohlgren *et al*., 1995). In each plot of 1000 m^2 was nested subplots of three different sizes. A 5 m × 20 m (100 m^2) subplot in the center, two 2 m × 5 m (10 m^2) subplots in opposite corners and ten 0.5 m × 2 m (1 m^2) subplots (six arranged systematically inside and adjacent to the 1000 m^2 plot perimeter and four arranged systematically outside and adjacent to the 100 m^2 subplot perimeter.

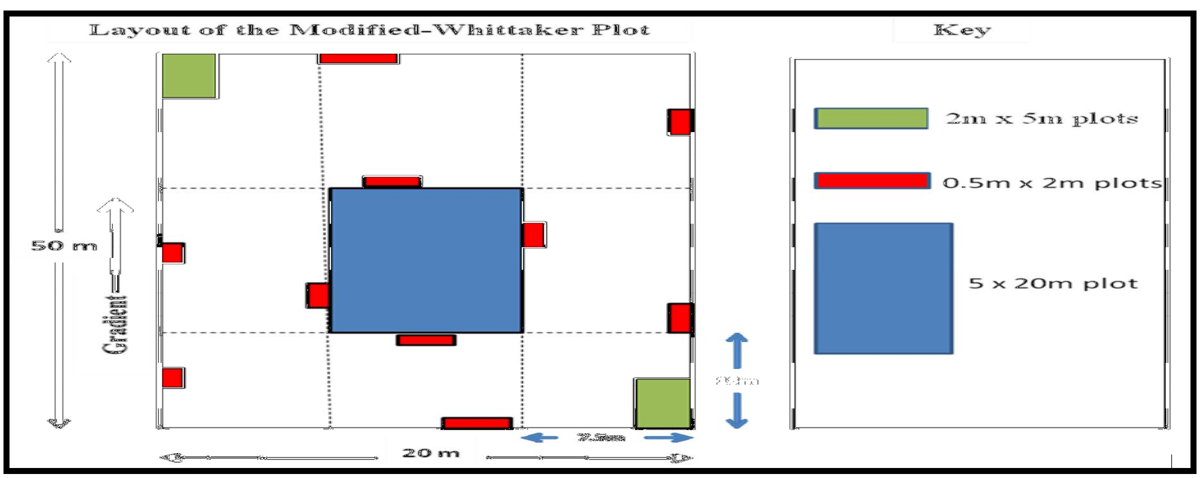

FIGURE 1. Field layout of a Modified-Whittaker plot design showing the three different sizes of sample plots nested into a large plot of 50 X 20 m

Five soil samples were taken from each of the four corners and center of each Modified-Whittaker plot using cores of 5 cm diameter. Due to the presence of rocks in some areas, it was hard to maintain a consistent core depth and thus core depths were varied between 8 cm and 15 cm. The five samples obtained were then pooled into a basin, mixed thoroughly to form one composite sample that was packed in a labeled plastic bag for laboratory analysis. Near the sites where soil cores were obtained, an undisturbed block of soil was also dug and taken for determination of soil structure and bulk density.

Laboratory analysis

The soil samples were air-dried for 48 hours, sieved with a 2 mm sieve, oven-dried at 60^0C for 24 hours and then used for analysis of selected chemical (pH, OC, OM, N, Ca, Mg, K, Na, CEC and available Phosphorus) and physical (bulk density, porosity, conductivity, structure and texture) properties. Soil particle size distribution (texture) was determined by the Bouyoucos hydrometer method (Gee and Bauder, 1986) while soil aggregate stability was determined by the wet sieving technique (Kemper and Rosenau, 1986). The soil cores were used in the determination of bulk density by the gravimetric method (Blake and Hartge, 1986). Soil pH was measured using a pH meter in a 1:2 soil: water ratio (Allen *et al*., 1976), nitrogen by the Kjeldahl procedure (ISSCAS, 1978), total P by the perchloric acid digestion method (Mehta *et al*., 1954) and soil organic carbon was determined using the modified Walkley-Black method (Mebius, 1960).

Data analysis

Analysis of variance was conducted using XLSTAT 2011 software to obtain the effects of land use, land cover and the interaction on soil physical and chemical properties using Fishers' LS means to separate the means at 95% confidence interval. Discriminant Analysis using XLSTAT 2011 was used to test whether differences exist among soil parameters in the three land cover types (bare, woody and herbaceous cover) and to visualize how different the land cover types are on a 2-dimensional map. The hypothesis tested here is that land cover change has no effect on soil properties and therefore the covariance matrices are equal within and between land cover types. Chi square test was used to analyze with in class variation and Wilks' Lambda test was used to test whether there are differences between the vectors of the means for the various land cover types.

RESULTS

Effect of land cover change on soil physical properties

Bare areas had significantly lower levels of sand ($p<0.0001$) and porosity ($p<0.0001$) and significantly high levels of clay content ($p<0.0001$) compared to herbaceous and woody covered areas (Table 1). There were no significant differences in percentage silt ($p>0.822$) and bulk density ($p>0.421$) between the three land cover types. Across production systems, the settled had significantly high levels of sand ($p<0.0001$) and porosity ($p<0.0001$) compared to semi-settled and non-settled while the non-settled had significantly high levels of clay ($p<0.0001$) followed by semi-settled and least in settled systems (Table 2).

TABLE 1. Least square means of percentage sand, clay and silt, bulk density (BD) and porosity across vegetation types. Means in the same column followed by different letters are significantly different at <0.05.

	Soil physical property				
Vegetation type	%Sand	%Clay	%Silt	BD	Porosity
Herbaceous	75.556a	12.389b	12.056a	1.481a	49.633a
Woody	76.889a	11.222b	11.889a	1.397a	48.328a
Bare	66.278b	22.611a	11.111a	1.462a	40.078b

TABLE 2: Least square means of percentage sand, clay and silt, bulk density (BD) and porosity across production systems. Means in the same column followed by different letters are significantly different at <0.05.

	Soil physical property				
Production system	%Sand	%Clay	%Silt	BD	Porosity
Settled	79.778a	9.722c	10.5a	1.455a	49.811a
Semi-settled	71.056b	15.667b	13.278a	1.457a	47.844b
Non-settled	67.889b	20.833a	11.278a	1.428a	40.383c

The interaction between production system and vegetation types showed that non-settled*bare had significantly high levels of clay ($p<0.0001$) and bulk density ($p<0.02$) and significantly lower levels of sand ($p<0.04$) and porosity ($p<0.001$) (Table 3).

TABLE 3. Effect of interaction between production system and vegetation types on percentage sand, clay and silt, bulk density (BD) and porosity. Means in the same column followed by different letters are significantly different at <0.05.

	Soil physical property				
Interaction	%Sand	%Clay	%Silt	BD	Porosity
Settled*Herbaceous	82.333a	8.5bc	9.167b	1.403ab	57.033a
Settled*Woody	80.333a	7.833c	11.833ab	1.550a	46.417b
Settled*Bare	76.667ab	12.833bc	10.5ab	1.412ab	45.983b
Semi-settled*Herbaceous	71.667b	12.5bc	15.833a	1.482a	47.117b
Semi-settled*Woody	77.667ab	10.0bc	12.333ab	1.442a	57.367a
Semi-settled*Bare	63.833c	24.5a	11.667ab	1.448a	39.05c
Non-settled*Herbaceous	72.667b	16.167b	11.167ab	1.558a	44.75b
Non-settled*Woody	72.667b	15.833b	11.5ab	1.2b	41.2c
Non-settled*Bare	58.333c	30.5a	11.167ab	1.527a	35.2d

Effect of land use and cover change on soil chemical properties

Table 4 summarizes the Least Square means used to separate the effects of land cover change on selected chemical properties of soil. The pH was significantly different between bare and herbaceous and bare and woody cover ($p < 0.0001$) but no significant differences between woody and herbaceous ($p > 0.875$). Organic carbon and organic matter were high in herbaceous followed by woody and least in bare with significant differences existing among the three cover types (herbaceous vs bare, $p < 0.0001$; herbaceous vs woody, $p < 0.007$; woody vs bare, $p < 0.0001$). Nitrogen was significantly different between herbaceous and bare ($p < 0.0001$) and between woody and bare ($p < 0.0001$) but was not significant between herbaceous and woody ($p > 0.09$). Ca was significantly different between woody and bare and herbaceous and bare ($p < 0.001$) but not significant between woody and herbaceous ($p > 0.96$). There were no significant differences in Mg ($p>0.131$), Na ($p>0.247$) and CEC ($p>0.06$) among the three cover types but high levels were found in herbaceous and least in bare. K was significantly different between herbaceous and bare ($p < 0.01$) but not different among other cover types. Available phosphorus was significantly different between woody and herbaceous vegetation ($p < 0.04$) but not significant between other cover types.

Across production systems (Table 5), the semi-settled system had significantly high pH ($p<0.04$) and Ca ($p<0.038$). Organic carbon ($p>0.21$), organic matter ($p>0.21$), total nitrogen ($p>0.72$), Mg ($p>0.331$), Ka ($p>0.6$), Na ($p>0.46$) and available phosphorus ($p>0.41$) were not significantly different across production systems whereas CEC was significantly lower in non-settled production systems ($p<0.001$).

The interaction between production system and vegetation type (Table 6) showed that the herbaceous vegetation under the semi-settled production system had significantly high levels of organic matter ($p<0.004$), total nitrogen ($p<0.003$) and Ca ($p<0.028$) while the interaction had no significant difference on pH ($p>0.08$), organic carbon ($p>0.1$), Mg ($p>0.19$), K ($p>0.340$), Na ($p>0.57$) and available phosphorus ($p>0.18$).

TABLE 4. Least square means used to separate chemical properties across vegetation types. Means in the same column followed by different letters are significantly different at <0.05

	Soil chemical property									
Vegetation type	pH	OC	OM	N	Ca	Mg	K	Na	CEC	Av.P
Herbaceous	4.753a	1.669a	2.879a	0.153a	3.907a	1.347a	0.394a	0.067a	12.867a	3.062b
Woody	4.783a	1.149b	1.981b	0.131a	3.933a	1.3a	0.320ab	0.052a	11.908a	5.604a
Bare	3.844b	0.389c	0.671c	0.063b	2.113b	0.91a	0.271b	0.051a	11.756a	4.351a

TABLE 5. Least square means used to separate chemical properties across production systems. Means in the same column followed by different letters are significantly different at <0.05

	Soil chemical property									
Production system	pH	OC	OM	N	Ca	Mg	K	Na	CEC	Av.P
Settled	4.361b	1.005a	1.733a	0.112a	2.894b	1.094a	0.304a	0.058a	12.350a	5.047a
Semi-settled	4.742a	1.249a	2.153a	0.121a	4.024a	1.388a	0.354a	0.062a	13.053a	4.502a
Non-settled	4.278b	0.954a	1.644a	0.113a	3.035b	1.075a	0.328a	0.049a	11.128b	3.468a

TABLE 6. Effect of interaction between vegetation cover and production system on soil chemical properties. Means in the same column followed by different letters are significantly different at <0.05

	Soil chemical property									
Production system*Vegetation type	pH	OC	OM	N	Ca	Mg	K	Na	CEC	Av.P
Settled*Herbaceous	4.5ab	1.212bc	2.090bc	0.115cd	2.402bcd	0.888ab	0.315ab	0.067ab	12.167a	2.812bc
Settled*Woody	4.85a	1.373abc	2.367abc	0.132bc	4.373a	1.293a	0.315ab	0.055ab	13.15ab	5.3abc
Settled*Bare	3.733c	0.431de	0.743de	0.090de	1.907cd	1.102ab	0.282b	0.053ab	11.733bc	7.028a
Semi-settled*Herbaceous	5.075a	1.984a	3.42a	0.181a	4.797a	1.524a	0.481a	0.085a	13.433ab	2.372c
Semi-settled*Woody	5.033a	1.214bc	2.093bc	0.141abc	4.01ab	1.444a	0.358ab	0.048b	11.975bc	6.838ab
Semi-settled*Bare	4.117b	0.548de	0.945de	0.041f	3.267abc	1.195ab	0.223b	0.053ab	13.75a	4.297abc
Non-settled*Herbaceous	4.683ab	1.984a	3.123ab	0.163ab	4.523a	1.628a	0.387ab	0.048b	13.0ab	4.002abc
Non-settled*Woody	4.467ab	0.861cd	1.485cd	0.120cd	3.417abc	1.163ab	0.288b	0.052ab	10.60cd	4.673abc
Non-settled*Bare	3.683c	0.189e	0.325e	0.057ef	1.165d	0.433b	0.310b	0.048b	9.783d	1.728c

Differentiating land cover types based on soil properties

Soil physical and chemical properties significantly varied within ($p < 0.0001$) and among the three land cover types (Wilk's Lambda test $p < 0.0001$). Presentation of centroids on factor axes shows that the land cover types are very well discriminated from one another using soil properties as the explanatory variables (Figure 2). Factor 1 (F1) which explains 89.45% of the variation among land cover types is correlated with N, OM, OC, pH, Porosity, Base saturation, Ca, Ksat and Mg (Table 7) while Factor 2 (F2) which explains 10.55% of the variation is correlated with K, C:N, CEC, Na, Av.P and Bulk density (Figure 2). The factor loadings for the bare, herbaceous and woody vegetation cover were -2.891, 1.516 and 1.374 respectively on F1 and 0.028, 0.846 and -0.874 respectively on F2. Soils under herbaceous cover had higher levels of OM, N, Na, CEC, K, OC and porosity while bare/un-vegetated soils were high in bulk density. As the land cover is converted from herbaceous to bare, the bulk density increases where as other properties associated with herbaceous cover decrease. Also, conversion of herbaceous cover to woody vegetation causes an increase in pH, Ca, hydraulic conductivity of the soil and available phosphorus. This showed that the soil properties of the three land cover types are distinguished on F1. Therefore, the three land cover types (bare, herbaceous and woody) significantly affect soil properties and can be properly differentiated on this basis.

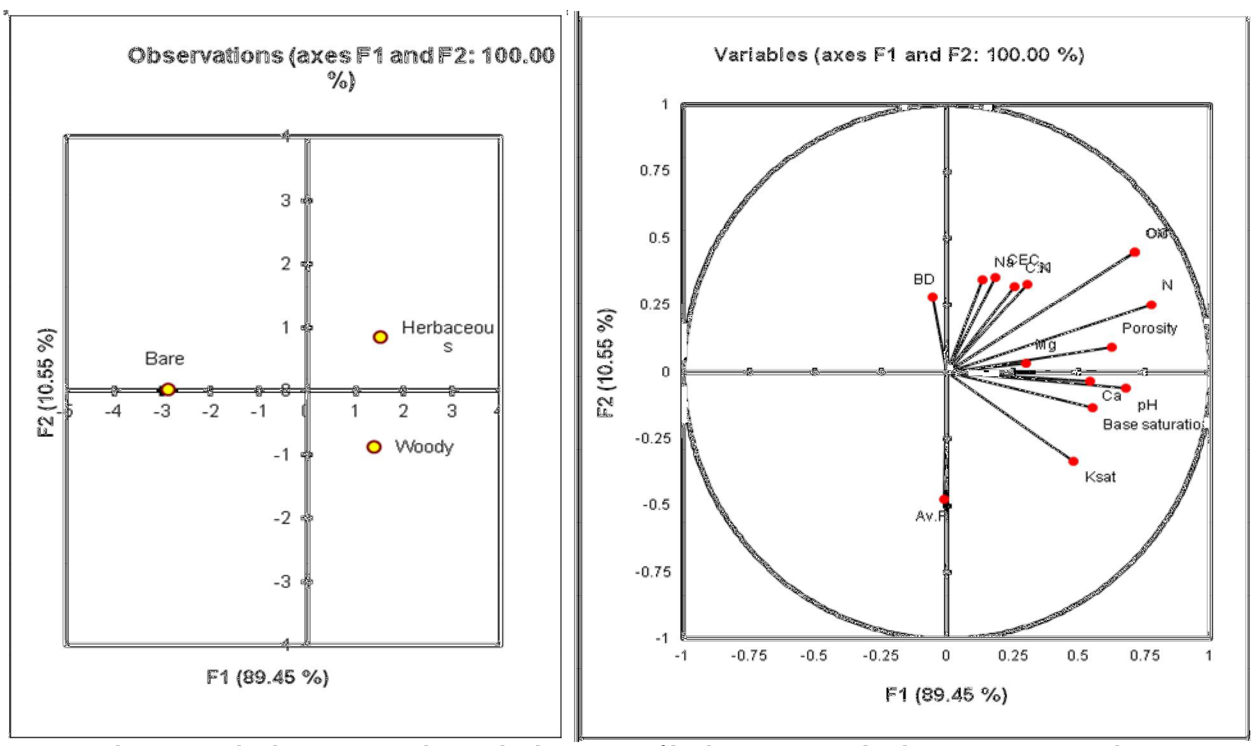

FIGURE 2. Ordination graphs showing centroids (weighted averages) of land cover types and soil properties respectively. Factor one (F1) on the horizontal axis accounts for 89.45% of the variability and factor two (F2) on the vertical axis accounts for 10.55% of the variability

TABLE 7. Correlations between soil properties and the two factors explaining their variability among the three land cover types

	Factors	
Variable	F1	F2
pH	0.677	-0.06
OC	0.714	0.449
OM	0.714	0.449
N	0.774	0.254
C:N	0.254	0.322
Ca	0.541	-0.034
Mg	0.299	0.032
K	0.303	0.329
Na	0.133	0.344
CEC	0.186	0.355
Ksat	0.482	-0.335
BD	-0.053	0.283
Av.P	-0.011	-0.476
Base saturation	0.553	-0.135
Porosity	0.625	0.095

Presentation of centroids together with the observations used in calculating them on the same factor axes (Figure 3) shows that the bare land is very distinctive from the herbaceous and woody cover types. There is no similarity in the soil properties from bare and herbaceous cover but a very slight similarity exists among the soil properties from bare and woody vegetation (5.6% overlap). The observations of herbaceous cover however overlap with those of woody cover by 72%.

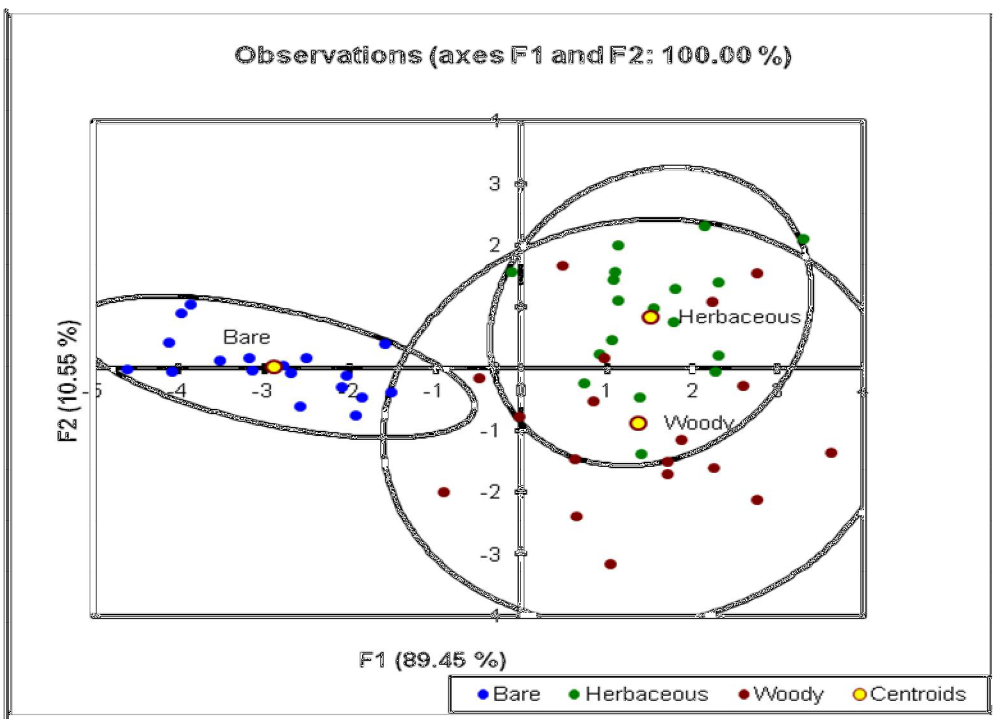

FIGURE 3. Ordination graph showing centroids of cover types and their observation

DISCUSSION

Generally, the soil nutrient pools under all land use and land cover types in the Nakasongola are lower than required nutrient levels for crop production as earlier reported by Radwanski (1960). Therefore, the significant differences in nutrient levels across land use and cover types are brought by the fact that rangelands have been consistently subjected to poor management practices that have exposed them to nutrient losses through soil erosion, increased plant uptake and emissions from soil surfaces. This is in line with the findings of Asner et al. (2004) who noted that any decline in nutrient levels from soils of relatively small stocks significantly affects the nutrient stocks and greatly impacts on productivity.

The prevalence of high levels of soil organic carbon, organic matter, nitrogen, Mg, K, Na, and CEC in soils under herbaceous cover and presence of lower levels of these nutrients under bare and woody cover can be explained by the increased loss of nutrients from bare and woody covers as a result of accelerated surface runoff. Overstocking and overgrazing of the herbaceous vegetation is the most notable factor for increased bare and woody encroachment in grassland ecosystems of Nakasongola. Overgrazing compacts soils leading to reduced infiltration and increased runoff (Branson et al., 1981; Trimble and Mendel, 1995) which causes a decline in soil nutrients in the bare and woody cover as compared to the herbaceous cover. These findings are supported by earlier studies in Nakasongola rangelands where high levels of nutrients were found in water sampled from valley tanks receiving surface runoff from un-vegetated catchments while low nutrients levels were found in valley tanks receiving water from a vegetated catchment (Zziwa et al., 2008). Similar results were obtained by Verity and Anderson (1990) who reported that organic C, P, N and S decreased with increasing rates of soil erosion down the slope. Asner et al. (2003) also reported that increased bare and woody cover caused a reduction of 25% and 80% in soil organic carbon and nitrogen respectively. This therefore shows that accelerated runoff from bare and woody covers increases nutrient from soils. Although grazing also contributes to nutrient losses from grazing systems (Asner et al., 2004), the losses from soil erosion are so enormous that bare soils are left with lower nutrient levels compared to herbaceous cover. More so, some of the nutrients lost through grazing are recycled back through manure deposition but those lost through erosion are not recycled back to the system. Hartley (1997), Hartley and Schlesinger (2000) also reported that woody encroachment on grasslands increases nitrogen losses through increased NO emission and reduces the nitrogen stocks, while Jackson et al. (2002) reported that woody encroachment on grasslands with more than 500 mm annual rainfall reduced soil carbon and nitrogen levels. Since annual rainfall for Nakasongola is higher than 500 mm, it is so probable that woody encroachment can result into a decrease in soil carbon and nitrogen.

Soil erosion greatly reduces N, Mg and K levels in soil and consequently leads to an increment in Ca levels because calcium carbonates are not easily eroded. As a result, woody soils which are more exposed to erosion than herbaceous in areas where the underground herbaceous cover is lost have slightly high pH and Ca levels. Because calcium carbonates bind phosphorous, soils with high Ca levels (woody and bare) consequently had high levels of phosphorous compared to herbaceous cover where Ca and pH were low. Similar findings were also obtained by Sparrow et al. (2003) who reported that soils exposed to erosion had less carbon and nitrogen but high levels of phosphorus. Verity and Anderson (1990) also found that increased soil erosion resulted into increased levels of calcium carbonate in surface horizons while inorganic P remained constant.

Because sand is more easily eroded than clay (Verity and Anderson, 1990; Brady, 1990), bare areas remain with more clay content, less sand and this subsequently lowers the porosity compared to woody and herbaceous vegetation covers.

Herbaceous vegetation under semi-settled production system had high levels of pH, organic carbon, organic matter, nitrogen, Mg, K, Na and CEC compared to a combination of other land use and cover systems practiced in Nakasongola. This is because semi-settled production systems that basically involve continuous grazing exert marginal pressure on land and allow for regeneration of pasture and soil reserves during movements from place to place. On the contrary, under the settled production systems, animals have to be kept on available land throughout the year. The inclusion of rotational grazing in settled production systems increases the grazing pressure on land compared to semi-settled systems where continuous grazing and transhumance are practiced (Heitschmidt and Taylor, 1991). Under the non-settled systems, there is less control over livestock numbers and movements hence exposing land to immense pressure that leads to intense degradation and loss of soil nutrients. Livestock grazing is a major component of rangeland ecosystems as far as their integrity and production are concerned, therefore land use and cover types that limit livestock activity impacts on ecosystem functioning and nutrient recycling, reduces soil organic carbon component and the sustainability of rangelands over the long term. The results of this study are consistent with those of Schuman et al. (2009) who found that continuously grazed lands had more soil organic carbon than in rotational grazing systems. Also, Briske et al. (2008) found that plant and animal production were better in continuous grazing than in rotational grazing systems.

The settled production systems involve more production costs in terms of initial and maintenance costs for fencing and water development. In turn producers tend to increase the stocking rates in order to substantially increase profits and keep their farms at break-even points (Manley et al., 1997; Dunn et al., 2010; Knight et al., 2011). This however exerts a lot of pressure on the land and in the long term leads to leads to reduction in the ecological condition and sustainable production of rangeland resources as noted by Norton (2003).

The existing distinction between land cover types based on soil properties signifies that the three systems have potentially different production potentials. With herbaceous cover being richer in the chemical and desirable physical properties, it is expected to be the most productive land cover system for rangeland ecosystems. As grasslands become degraded, leading to a reduction in herbaceous layer, woody cover increase as a result of reduced competition (Scholes and Archer, 1997; Van Auken and Bush, 1997; Kraaij and Ward, 2006). Because woody encroachment can progress on both herbaceous and bare ground and co-exist with the two land cover forms, there is an overlap between woody cover the other cover types. Asner et al. (2004) also reported that increase in woody component in grassland ecosystems may occur without significant reduction in herbaceous cover (woody encroachment) or with complete disappearance of herbaceous layer (desertification). The greater overlap between woody and herbaceous cover however indicates that woody encroachment in grasslands can proceed without prior degradation of the grassland ecosystem. This is supported by earlier findings which indicated that changes in rainfall, temperature and carbon dioxide concentrations and elimination of fire use can significantly drive woody encroachment in grasslands (Polley *et al*., 1992; Johnson *et al*., 1993; Brown and Archer, 1999; Higgins *et al*., 2000; Roques *et al*., 2001; Hudak and Wessman, 2001; Kraaij and Ward, 2006; Dempewolf, 2007; Moustakas *et al*., 2010; Ward 2010).

Although bare ground is basically derived from former herbaceous covered lands, there is no interaction between the two systems. This therefore indicates that there is a limited ability of herbaceous vegetation to naturally re-establish on completely bare ground and thus reclaiming bare land back into grasslands will require more external interventions and inputs because the soils have limiting levels of organic matter and other nutrients as well as an exhausted seed bank due to high rates of soil erosion. Earlier studies in the this area suggested that effective rehabilitation of degraded rangelands (re-establishment of pasture on bare lands) involved ploughing of land, use of manure and reseeding (Kironchi, 1998; Mugerwa et al., 2008).

CONCLUSION

The conversion of grasslands into woody and bare have caused enormous levels of soil degradation with the conversion to bare ground having surpassed the recuperative capacity of land to regain its original state. The soils are so degraded, lost their production potential and thus more external investment is needed to rehabilitate the bare grounds back into grasslands. Because woodlands have a potential of encroaching on pasture lands that have been eventually left bare due to degradation, failure to devise management intervention to reclaim bare ground back into grasslands and failure to develop and impose stringent rangeland management practices to protect the integrity of rangelands may lead to their ultimate conversion into woodlands.

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