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Effect of Slope Position and Land-Use Changes to Bio- Physical Soil Properties in Nakasongola Pastoral Rangeland Areas, Central Uganda

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1. Introduction

Land degradation, which includes degradation of vegetation cover, soil degradation and nutrient depletion, is a major ecological problem in Uganda. It is estimated that fertile top soil is lost at a rate of one billion cubic meters per year, resulting in massive environmental degradation and constituting a serious threat to sustainable agriculture and forestry (Yost and Eswaran, 1990).

Forests and the benefits they provide in the form of wood, food, income, and watershed protection have an important and critical role in enabling people to secure a stable and adequate food supply. Deforestation and land degradation, however, are impairing the capacity of forests and the land to contribute to food security, and to provide other benefits, such as fuel wood and fodder in Uganda (Siriri *et al.*, 2000). Ugandan environmental issues are causing a great concern because the expansion rate of such major problems as drought, desertification, water pollution, is reaching an alarming stage (NEMA, 2001).

In Nakasongola district, the presence of steep slopes subject to cultivation since many years, has led to serious soil erosion. The lag in agricultural productivity advancement behind population growth has caused intense land use conflicts, particularly between the agricultural and the forestry sectors. To compensate for the low agricultural productivity, deforestation for arable land expansion has been the principal land use conversion employed in Uganda and in particular in Nakasongola for centuries. There are several repercussions of such land use conversion, the most important in Uganda's and in particular in Nakasongola context being accelerated soil erosion and deterioration of soil nutrient status (FAO, 1986). However, Nakasongola is known not only for the severity of land degradation, but also, since the last decades, for the concentrated efforts taking place to redress these problems including construction of stone terraces and soil bunds, protected areas and afforestation (Osiru and Hahn, 1994).

The protected areas, which are a type of land management implemented on degraded, generally open access land, are a mechanism for environmental rehabilitation with a clear biophysical impact on large parts of the formerly degraded commons. In places where protected areas are established, particularly in the western part of the country, they constitute green spots with considerable species diversity. The ability of rehabilitation areas to recruit and sustain new life forms is a true measure of their contribution to biodiversity and forest resource conservation (Yost and Eswaran, 1990; Tucker and Murphy, 1997).

In protected areas, it is generally believed that the land resources such as soil, wild flora and fauna, or water will be protected from degradation. Although the restoration ecology and buffering effect of protected areas have been well studied, there are relatively few studies in the region, which would provide a measure of the success or failure of protected areas as one strategy to help prevent decline of soil fertility and adverse effect of water erosion, thereby increasing agricultural productivity. Above all there are no quantitative studies that analyse the effectiveness of protected areas in improving soil chemical and physical properties.

Therefore, the objectives of this study were to asses the impact of protected areas on soil properties, and investigate the relationship between age of protected areas and their effectiveness in improving soil chemical and physical properties.

2. Materials and methods

2.1 Study area

Nakasongola District is located on the Bombo - Gulu highway 114 Km north of Kampala. It covers an area of 3,424 km^2 of land and boarders with Apac district in the northeast, Mukono district in the east, Masindi in the west and Luwero district in the south (Figure 1) . The area lies on the central plateau between 1000 and 1400 m above sea level. The topography is characterized by extensive uniform undulating plains with broad seasonal swamps.

The soils are mainly weathered basement complex formations of the precambrian age, which consists mainly of metamorphic and igneous rocks, largely composed of gneisses and granites. Remnants of the older mid-tertiary surface are found as relic murram and iron stones in some places. The annual rainfall varies from 875 – 1120 mm with two marked dry seasons. The main vegetation types are woodland and woodland savanna, thicket and soft wood plantations. Much of the cultivated land exists as patches with in the woodland.

The district has a total population of 528,126 people, the population density is about 230 persons per km^2, and the growth rate is 2.7 %. There are three ethic groups; the Baganda (70%) and Baruli (28) and others (2%). Subsistence agriculture is the major economic activity employing about 89% of population.

Rocks outcropping in the study area belong to the Mesozoic sedimentary series and Tertiary basalt flows. Soils of the specific study sites are developed on lime rich parent material. Using the FAO-UNESCO soil classification system, they were classified as calcaric Cambisols. In the study area, the erosion rate is extremely serious and it is common to observe ground surfaces that have been incised strongly by rill and gully erosion.

The study area has a semi arid continental climate with an average annual rainfall of 615 mm/yr with extreme values of 290 and 900 mm (Figure 2). The rainy season starts in June, peaks in July and August and trails off in September. The study sites have 53-104 rain days per year with mean of 80 days. According to the agro-climatic classification system, which is traditionally used in Uganda, all the study sites are classified as mid altitude.

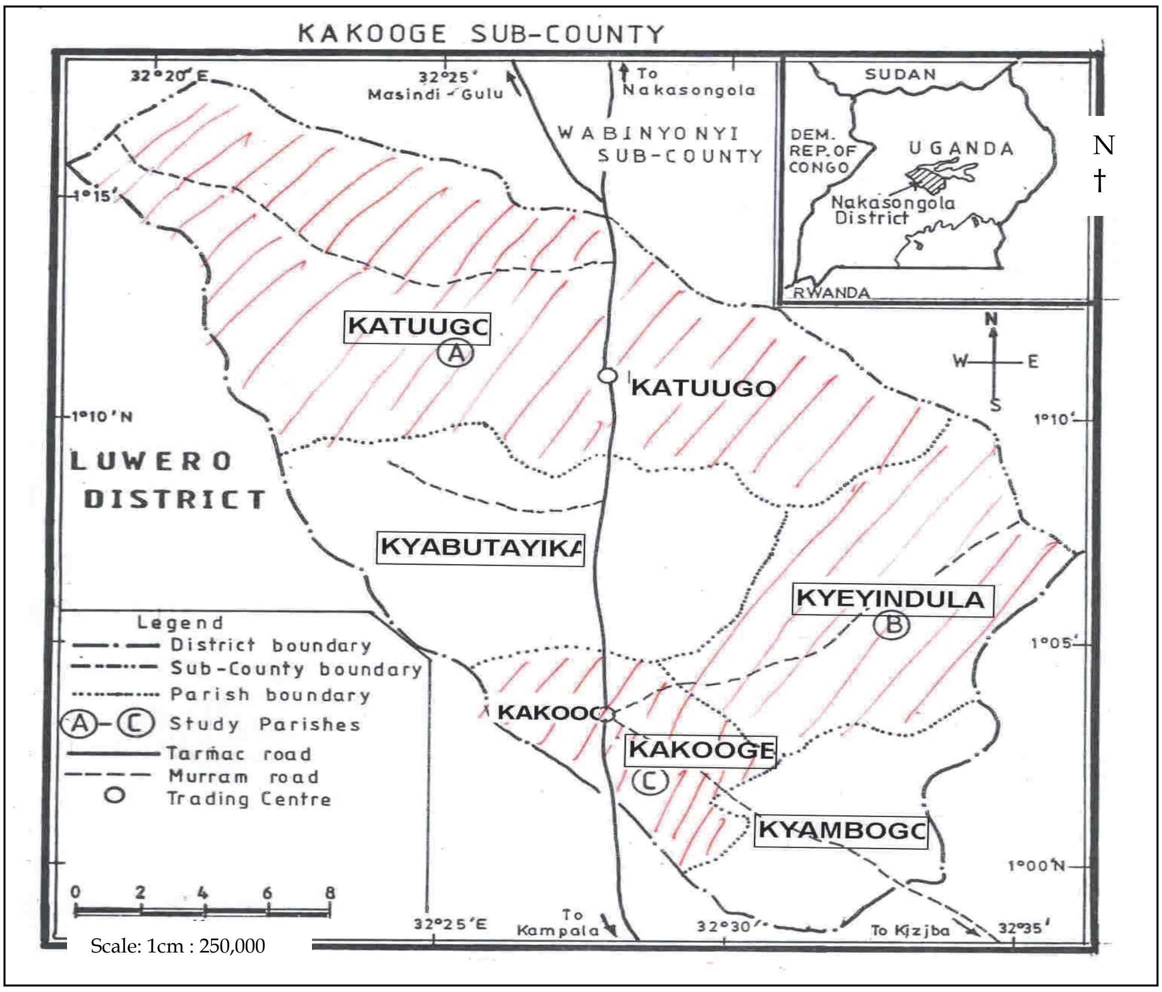

Fig. 1. Location of the study district and specific study site at Kakooge sub-county

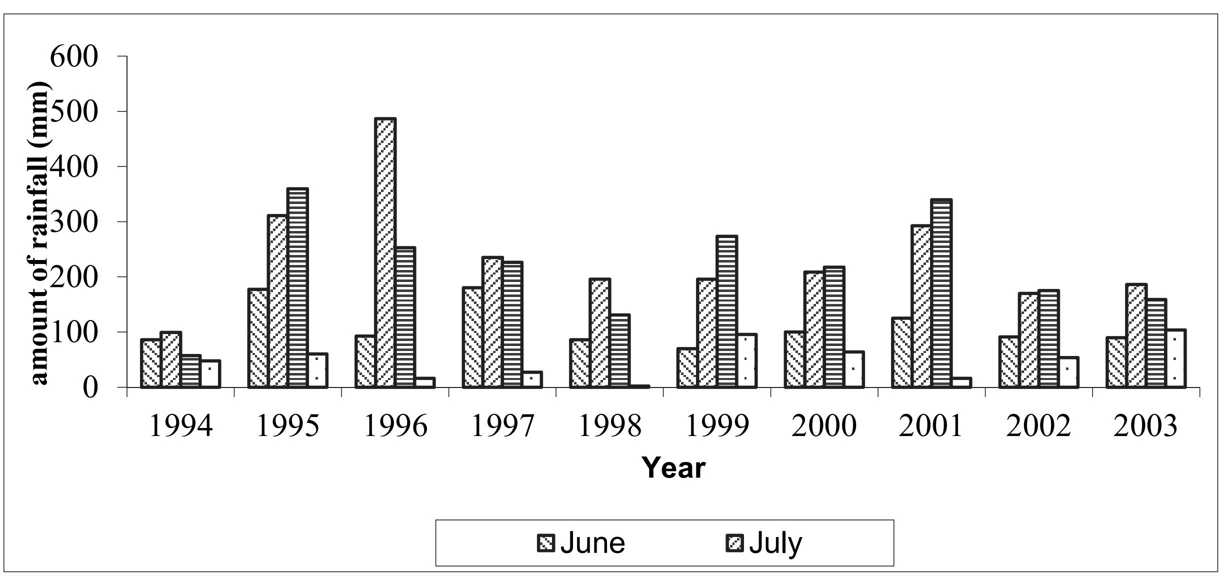

Fig. 2. Monthly rainfall of the study sites (source: Uganda Meteorological Division, Ministry of Water, Lands and Environment, Kampala, Uganda).

The typical land use in the study area is range land and protected areas on the steep slopes and crop land in the flats. The vegetation of the study area is largely dominated by *Acacia etbiaca*, and *Euclea shimperi*. Under-storey vegetation of the study sites is dominated by a very diverse assemblage of grass and herbs most of which are palatable for livestock. Crops are mainly cassava, maize, and sweet potatoes. Crop yields are low (500kg/ha on average), with great variability depending on rainfall and the location of the cultivated lands. According to the district's Agricultural office, the average land holding is 0.46-0.76 ha per household.

Within the Nakasongola district, twelve hillslopes ranging from 3.5 to 48.5 ha were selected based on similarities in lithology, soils, climate and land use. Out of the twelve sites selected, six are protected areas and the remaining six are free grazing lands. To examine the influence of age since protection five and ten year's old protected areas each having three replicates were selected for the study. Features of the specific study sites are included in table 1.

Land use	Slope class	Year of closing	Area (ha)	Slope Steepness (%)	Slope Length (m)	Vegetal canopy		Ground vegetation		Estima-ted soil loss t/ha/year (USLE)[1]
						Type	Cover (%)	Type	Cover (%)	
10 AC	US	1994/95	20.3	24	125	BU (2m)	43	TWSBG	58	16.3
	MS		40.8	19	274	BU (2m)	31	TWSBG	60	6.8
	FS		34.5	10	290	BU (2m)	32	TWSBG	52	2.6
5 AC	US	1999/00	6.8	37	80	BU(.5 m)	28	GTWSB	23	98.5
	MS		6.8	33	73	BU(.5 m)	30	GTWSB	38	68.7
	FS		5.4	18	86	BU(.5 m)	29	GTWSB	38	27.7
C_1	US	--	12.7	22	147	SBU	4	TWSB	5	57.4
	MS		10.2	25	81	SBU	5	TWSB	5	80.2
	FS		6.5	11	111	SBU	10	TWSB	9	27.9
C_2	US	--	10.7	27	82	SBU	6	TWSB	6	121.5
	MS		7.7	29	64	SBU	7	TWSB	11	96.2
	FS		7.3	13	80	SBU	4	TWSB	6	25.0

10AC, 5 AC: 10 and 5 years old protected areas respectively. C_1 and C_2 are free grazing lands used as a control for 10 and 5 years protected areas. US, MS, and FS are Upper, Middle and Foot slope. TWSBG, GTWSB, and TWSB; tall weeds and short bushes with grasses, grasses with tall weeds and short bushes and tall weeds with short bushes respectively. BU (2m) = bushes of 2 meter effective height; Bu (0.5) = bushes of 0.5 meter effective height and SBU= short bushes.
[1] = predicted through application of Universal Soil Loss Equation (USLE);.

Table 1. Average characteristics (n = 3) of the specific study sites

2.2 Experimental design

Five and ten year's old protected areas and free grazing lands were selected in the middle altitude agro-ecological zone (mid latitude) for this study. Each of the sites was replicated three times over the study area. Each of the study sites (protected area and free grazing lands) was divided into three slope positions, upper slope (US), middle slope (MS) and foot slope (FS). The US position is the uppermost portion of each study site. It receives little or no overland flow but may contribute runoff to downslope areas. The MS position receives overland flow from the upperslope and contributes runoff to the FS. The FS represents the lower part of each study site.

2.3 Soil sampling and laboratory analysis

Within each position in protected areas and free grazing land, transects were laid out and eight soil sampling points along transect were selected using systematic random sampling. Samples of 0-15 cm soil depth were taken from the eight points of each transect. The eight samples were combined in a large bucket and mixed thoroughly to form a composite soil sample; 36 composite samples were collected from all the sites. Major live plant materials (roots and shoots) in each sample were separated by hand and discarded. The soil samples were air dried, grinded and passed through a 2 mm sieve before the determination of soil nutrients. Standard soil test procedures for observation and analysis in Kyambogo University Soil Science Laboratory were used for all nutrients and physical soil parameters. Organic matter was determined by Walkley Black method and total Nitrogen was determined by Kjeldahl method (Bremmer and Mulvany, 1982). Available Phosphorus was determined by Olsen method (Olsen and Sommers, 1982). Ammonium and Sodium acetate methods were used to determine exchangeable bases and cation exchange capacity (Osiru and Hahn, 1994). Calcium and Magnesium values were then red using Atomic Absorption Spectrophotometer while Potassium and Sodium were determined by flame photometer. The pH and EC of the soil samples were determined by pH and conductivity meter using supernatant suspension of 1:5 soil water ratios. Particle size analyses of the sampled soils were determined in soil suspension by Hydrometer method (Gee and Bauder, 1982). Bulk density was determined by core method through measurement of volume and mass (Blake and Hartge, 1986). Total porosity was determined experimentally by the water displacement method and calculation using bulk density values.
Moreover, the Universal Soil Loss Equation (USLE) was used (Wischmeier, 1976, Table 1) for the purpose of characterizing the severity of erosion in the study sites and generates supplemental data (Yost and Eswaran, 1990). Individual interviews using structured questionnaires were also conducted to understand farmers' perception on the role of protected areas.

2.4 Statistical analysis

Statistical analyses were performed to test the influence of land use conversion and age of protected areas on soil chemical and physical properties using one-way analysis of variance (ANOVA). Mean comparisons were made using the Tukey Honest Significant Difference (HSD) test with $p < 0.05$. Two - way ANOVA was also used to see whether there is an interaction effect between the two main independent variables: age and slope gradient. The independent variables used in this study were land use, slope gradient and age of protected areas. All the analyses were conducted through Statistica 6.0 program.

3. Results

3.1 Soil chemical properties and land uses

The soils of free grazing lands and protected areas differed considerably in content of soil organic matter (SOM), total Nitrogen (TN), available Phosphorus (AP) and exchangeable bases and cation exchange capacity (CEC) (Table 2), with significantly higher ($p < 0.05$) values found in protected areas than in free grazing lands. Two - way analysis of variance also revealed that age of protected areas was highly significant ($p < 0.01$). Slope effect was not significant. There was a tendency of significant interaction effect ($p = 0.07$) indicating that the influence of slope changes with age.

Land use & slope position	Soil nutrients						
	SOM (%)	TN (%)	AP (ppm)	K cmol(+)/kg	Ca cmol(+)/kg	Mg cmol(+)/kg	CEC cmol(+)/kg
10 AC US	2.4^{ab}	0.27^{ab}	4.5^{ab}	0.32^{ab}	9.2^{ab}	0.4^{a}	52.2^{ac}
10 AC MS	2.8^{ab}	0.34^{ab}	5.8^{ab}	0.34^{ab}	5.7^{a}	0.5^{a}	54.5^{a}
10 AC FS	3.0^{a}	0.34^{ab}	6.0^{ab}	0.36^{ab}	8.7^{ab}	0.8^{ab}	55.5^{a}
5 AC US	2.8^{ab}	0.35^{ab}	4.6^{ab}	0.59^{ab}	11.0^{ab}	1.8^{b}	56.4^{a}
5 AC MS	3.1^{a}	0.37^{ab}	5.1^{ab}	0.63^{ac}	11.0^{ab}	0.8^{ab}	56.6^{a}
5 AC FS	3.2^{a}	0.57^{a}	6.8^{a}	0.70^{ac}	5.1^{a}	0.4^{a}	58.0^{a}
C_1 US	1.5^{b}	0.20^{b}	3.0^{b}	0.22^{b}	15.4^{ab}	1.3^{ab}	39.6^{b}
C_1 MS	1.5^{b}	0.21^{b}	3.7^{ab}	0.23^{b}	17.6^{ab}	1.4^{ab}	40.9^{b}
C_1 FS	1.9^{ab}	0.24^{b}	4.1^{ab}	0.22^{b}	27.0^{b}	1.4^{ab}	41.0^{b}
C_2 US	1.8^{ab}	0.23^{b}	3.7^{ab}	0.76^{c}	2.7^{a}	0.6^{a}	48.3^{dc}
C_2 MS	1.8^{ab}	0.26^{ab}	2.8^{b}	0.70^{c}	18.0^{ab}	0.5^{a}	45.5^{db}
C_2 FS	1.4^{b}	0.25^{ab}	3.6^{ab}	0.55^{bc}	6.4^{a}	0.2^{a}	45.4^{db}
F value	5.398**	2.506*	2.473*	7.633**	3.488**	1.733*	9.015**

Different letters along the column indicate significant differences between mean values of the different land use types at $p < 0.05$ (Tuckey HSD).
*, ** significant at 0.05 and 0.01 level of significance respectively.
SOM - soil organic matter; TN -total Nitrogen; AP – available Phosphorus; and CEC – cation exchange capacity.
5 AC – five years protected areas; 10 AC – ten years protected areas; C_1 – free grazing land used as a control for 10 years protected areas and C_2 – free grazing land used as a control for 5 years protected areas. US, MS and FS are upper, middle and foot slopes respectively.

Table 2. Average soil nutrient content ($n = 3$) of 0-15 cm soil depth for the land use types and slope position

The mean SOM content varied between 1.4 and 3.2 % (Table 2). Multiple comparison of SOM revealed that SOM levels under five and ten years protected areas were significantly higher than in C_1 and C_2. The mean CEC of the sampled soils varied between 39.6 and 58.0 cmol (+)/kg and had a similar pattern to SOM. Mean TN content varied between 0.20 and 0.57 %. Comparison of means revealed that the protected areas had significantly higher total Nitrogen content than C_1 and C_2. Mean AP content varied between 2.8 and 6.8 ppm and displayed similar pattern to TN. The mean value of exchangeable K, varied between 0.22

and 0.76, Ca between 2.7 and 27 and Mg between 0.2 and 1.8 cmol(+)/kg-soil. Except Ca, the level of exchangeable bases in the sampled soils showed the same trend as the other soil parameters for multiple comparisons.

The result of pH tests revealed that 75 % of the sampled sites had moderately alkaline soils (pH between 7.4 and 8.4) and 25 % of the sampled sites had neutral soils (pH 6.6-7.3). The level of soluble salts in the sample sites was also low, that is less than 1 mmhos/cm. Analysis of variance shows that there were no a significant differences between protected areas and free grazing lands (at $p < 0.05$) for pH and EC values.

In protected areas, an increasing trend was observed in soil organic matter, total Nitrogen, available Phosphorus and exchangeable Potassium from US to FS position (Figure 3). However, such trend was not clearly seen in free grazing lands.

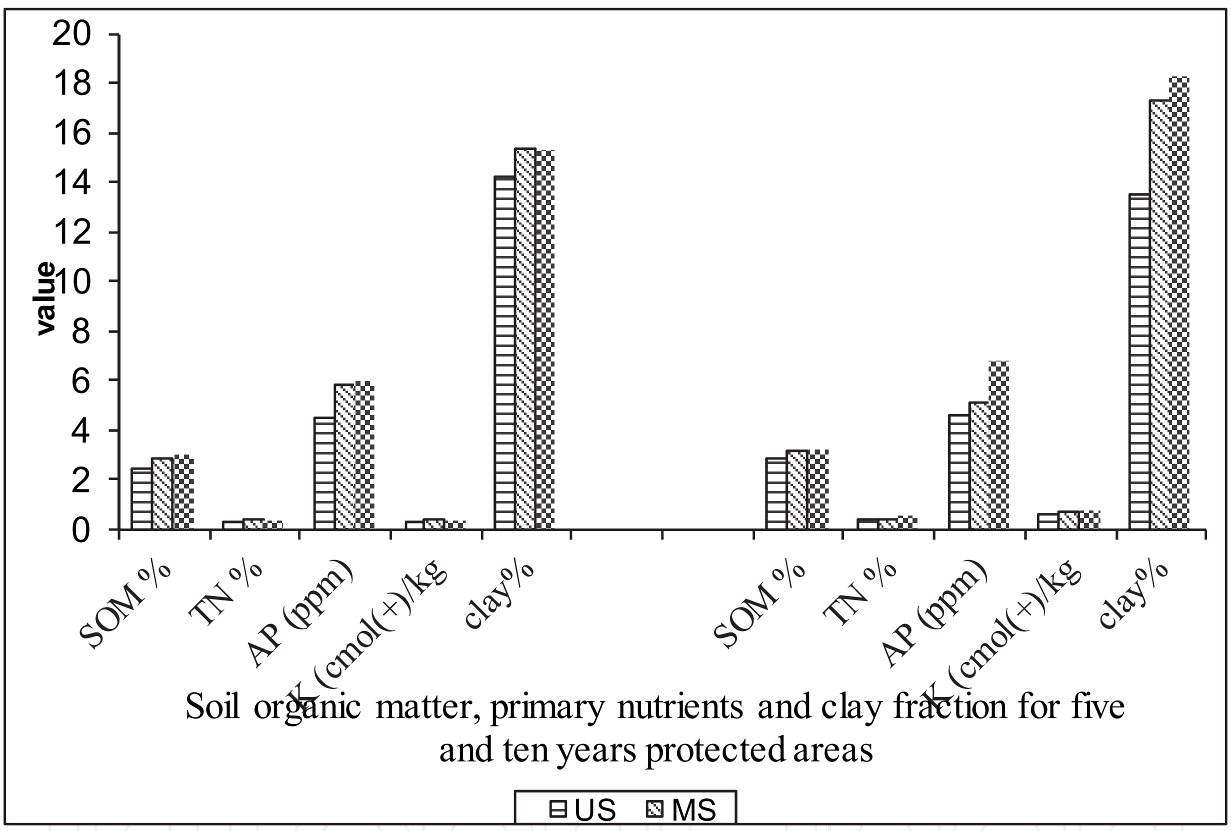

Fig. 3. Soil organic matter, primary soil nutrients and clay fraction in relation to slope positions in protected areas.

3.2 Soil nutrient stocks and land uses

In this study, total amount of nutrients stored at 0-15 cm soil depth were determined using bulk density values of each slope position of each site (Table 3). There were considerable differences in total amount of nutrients stored in the upper 15 cm soil between protected areas and free grazing lands. The mean value of SOM stock of ten year protected areas was higher by 40%, TN by 31% and AP by 40% than its control C_1. Mean value of SOM, TN, and AP stock of five year protected areas was higher by 44%, 39%, and 40% than its control C_2. However, the nutrient stocks in five and ten years protected areas were nearly similar.

Land use and slope position	Soil nutrient stocks (kg/ha)					
	SOM	TN	AP	K	Ca	Mg
10 AC US	45810	4938	8.2	223	3286	84
10 AC MS	50598	6097	10.7	256	2126	110
10 AC FS	54119	6073	11.7	237	3175	157
Mean for the land use type	**50176**	**5703**	**10.2**	**239**	**2863**	**117**
5 AC US	53548	6658	8.7	446	3743	377
5 AC MS	52289	7204	9.0	411	4176	167
5 AC FS	62037	9255	12.0	512	1985	90
Mean for the land use type	**55958**	**7705**	**10**	**456**	**3301**	**211**
C_1 US	29211	4714	4.4	177	6062	305
C_1 MS	27607	3880	6.3	172	6715	316
C_1 FS	36671	4024	7.7	167	10474	322
Mean for the land use type	**31163**	**4206**	**6.1**	**172**	**7750**	**314**
C_2 US	35544	4588	6.0	598	1084	149
C_2 MS	30446	4621	5.0	498	6578	108
C_2 FS	27125	4829	7.0	416	2302	57
Mean for the land use type	**31038**	**4679**	**6**	**504**	**3321**	**105**

See table 2 for abbreviations

Table 3. Average (n = 3) soil nutrient stocks of 0-15cm soil depth for the land uses and slope positions

3.3 Soil nutrient correlations

Some values found in this study were significantly correlated with each other (Table 4). Soil organic matter was correlated positively and significantly with total Nitrogen (TN), AP, and CEC (at $p < 0.05$).

	SOM	TN	AP	CEC	Ca	K
TN	0.54*					
AP	0.36*	0.45*				
CEC	0.55*	0.55*	0.56*			
Ca	-0.31	-0.28	-0.21	-0.52*		
K	0.21	0.30	0.18	0.36*	-0.21	
Mg	0.12	-0.11	-0.18	-0.32	0.51*	-0.10

Numbers are correlation coefficients (r). N = 36
* significant at 0.05 level of significance

Table 4. Correlation between soil nutrients

3.4 Land use and soil physical properties

The mean values of soil bulk density (BD) at a depth of 0-15 cm varied between 1.11 and 1.34 g/cm^3 (Table 5). The mean values of total porosity varied between 49 and 58 %.
Analysis of variance shows that there was no significant difference between land uses (at $p< 0.05$) on their BD and porosity values. Texture of the 0-15 cm soil depth was sandy loam at all sampled sites (Table 5).

4. Discussion

4.1 Effects of protected areas

The higher SOM, TN and AP contents in protected areas compared to those from free grazing lands can be explained by the difference in soil erosion and biomass return. Reduced erosion is expected to occur in well developed protected areas because the canopy formed by the mature shrubs and under-story vegetation shields the soil from the erosive energy of the falling raindrops and thereby protects it from splash erosion and surface or sheet erosion. The lowest soil loss (8.5 ton/ha /yr) calculated using USLE was found in ten years old protected areas and is mainly due to the relatively high vegetation canopy cover (31-43%) by 2 m effective height bushes, and ground vegetation cover of 52 – 60% (Table 1). In contrast, the higher soil loss (81 ton/ha /yr) predicted for free grazing land is the result of very low vegetation cover (4 - 7%) and ground vegetation cover of less than 10% (Table 1).
Our result is in agreement with other studies. The study conducted by Jiang *et al.*, (1996), showed that soil loss decreases exponentially with increasing degree of cover by mulch. Siriri and Bekunda (2001) revealed that the median rate of soil erosion in polygons of different land uses decreased in the following pattern: bare soil > open canopy forest > pasture > protected canopy forest. A report by Mullar-Harvey *et al.*, (1985), indicates that under a tropical monsoon climate, the establishment of forest on

eroded slopes reduced annual soil erosion from about 15000 to 3000 m^3/ km^2 over a period of 10 years.

Land use types	slope position	Bulk density (gm/cm^3)	Porosity (%)	Particle size distribution (%)			Textural class
				Sand	Silt	Clay	
5 AC	Upper slope	1.11	58.02	57.9	28.6	13.5	SL
	Middle slope	1.26	52.33	53.1	29.6	17.3	SL
	Foot slope	1.28	51.51	52.1	29.6	18.3	SL
	Average value	**1.22**	**53.96**				
10 AC	Upper slope	1.19	54.75	61.23	24.5	14.22	SL
	Middle slope	1.28	51.62	62.3	22.4	15.3	SL
	Foot slope	1.20	54.4	59.9	24.8	15.3	SL
	Average value	**1.23**	**53.60**				
C_1	Upper slope	1.34	49.4	62.3	18.68	19.02	SL
	Middle slope	1.26	52.33	62.83	21.34	15.82	SL
	Foot slope	1.28	51.68	62.3	21.34	16.35	SL
	Average value	**1.29**	**51.14**				
C_2	Upper slope	1.34	49.29	59.64	27.9	12.44	SL
	Middle slope	1.20	54.5	61.24	25.24	13.51	SL
	Foot slope	1.26	52.25	58.57	27.38	14.04	SL
	Average value	**1.27**	**52.02**				
	F value	0.933^{ns}	0.936^{ns}				

SL = Sandy loam; ns = non significant (at $p < 0.05$, Tukey HSD).

Table 5. Average (n = 3) soil physical properties of 0-15cm soil depth of the land uses and slope positions

The higher SOM in protected areas also improves the soil physical properties such as soil structure and total soil porosity. This in turn increases the amount of water infiltrated into the soil and decreases the amount of runoff that can be generated from a given amount of rainfall. Water infiltration in the soil is enhanced by both preferential flow along trees roots and accumulation of absorbent humus on the soil surface, thereby significantly reducing the volume, velocity, and erosive and leaching capacity of surface runoff (Jiang *et al.*, 1996). However, land use for free grazing land is related to soil management practices that have commonly been very destructive to the soil and have caused serious erosion. Therefore, differences in soil erosion control contribute to the significant difference in nutrients in protected areas and free grazing land soils.

In addition, less biomass return causes the reduction of SOM, TN and AP in free grazing lands (Mullar - Harvey *et al.*, 1985; Shariff *et al.*, 1994). The most evident impact of grazing on the rangeland ecosystem is removal of a major part of above ground biomass by livestock. Therefore the input of aboveground litter to the soil decreases. Any reduction in litter inputs may have important consequences for soil nutrient conservation and cycling (Shariff *et al.*, 1994). Grazing may also have an indirect effect on soil characteristics through change in plant species composition. This is mainly because plant species has a significant impact on decomposition and nutrient cycling at ecosystem levels.

The similar pattern displayed among SOM, TN and AP for multiple comparison of means can be explained by the influence of soil organic matter in nutrient retention and supply (Brubaker *et al.*, 1993). Among soil properties, total organic carbon is a sensitive soil quality indicator suggesting that within a narrow range of soil, it may serve as a suitable indicator of soil quality (Mullar-Harvey *et al.*, 1985). Moreover, the soil organic matter fraction may offer further insight into soil fertility changes and the sustainability of management history.

The insignificant differences in soil bulk density and porosity among protected areas and free grazing lands can be explained by the coarse texture nature of the study sites and low amount of preexisting soil moisture. Preexisting soil texture and moisture conditions are important variables to consider when investigating the relationship between soil compaction and grazing intensity. The effect of grazing intensity in increasing bulk density is pronounced in wet and fine textured soils. The slight difference found in this study can be explained by their difference in SOM content and compaction of the sites by livestock trampling effect.

The role of soil organic matter in storing and supplying nutrients explains the significant correlation between SOM and soil nutrients such as TN and AP and CEC. Despite the fact that one of the effects of organic matter is to retain cations and protect them from leaching and from removal by runoff, organic matter is inversely correlated with Calcium. This is mainly due to the effect of soil erosion and parent material. In free grazing areas, where soil erosion is more severe than in protected areas, most of the top soil is removed and the soils that were sampled partly included subsoils, highly influenced by lime rich parent material.

The positive impact of protected areas on the amount and availability of soil nutrients has many influences on the livelihood of the local people near the study sites. The amount of grass produced in a given area increases and the local people get supplemental animal feed and thatching material. The regeneration of indigenous trees is also improved by the increased availability of water and nutrients. Besides, farmers benefit from the protective effect of protected areas. This is mainly because protected areas reduce runon and soil erosion in farm lands located below the protected areas. This in turn leads to an increase in crop production (Siriri *et al.*, 2000).

4.2 Effect of slope position

Because the different slope positions have similarities in vegetal canopy and ground vegetation cover (table 1), the variation in soil nutrients at different slope positions in protected areas can only be explained through the difference in soil erosion rates. Results from this study showed that upper slope positions in protected areas had higher rate of soil erosion. This is mainly due to the steepness of the US positions compared to MS and FS positions. Nutrients in the upper slope positions can be dissolved and washed by runoff and might be deposited in the middle and foot slope positions.

However, slope position effect in free grazing lands was inconsistent. This can be explained by differences in vegetation removal, related to accessibility by livestock and human beings; depending on the position of villages nearby. This difference creates a difference in C input which influences SOM content, and thereby related soil nutrients such as total Nitrogen and available Phosphorus. The amount of predicted soil loss was not also consistent like in protected areas where it showed a decreasing trend from US to FS position. Hence, there is no clear trend among the slope positions in free grazing lands.

5. Conclusions

This study assessed the effects of land-use conversion and slope position on soil chemical and physical properties. Significant differences (at $p < 0.05$) between land uses were found for SOM, TN and AP and exchangeable bases and CEC. Five and ten years' protected areas had higher levels for SOM, TN, AP and CEC compared to free grazing lands. The difference in soil nutrients content between the land use types is mainly due to differences in soil erosion and biomass return.

From the technical point of view, under the present land use management and climate conditions of the study area, free grazing areas in hilly lands should be changed to protected areas before soil organic matter and other nutrient contents are depleted more. Besides, the erosion processes may be very active resulting in further degradation. However, the socio-economic dimensions of protecting free grazing lands and changing them into protected areas (for example, impact on livestock and crop production in short run) should also be considered before making a decision.

6. Acknowledgement

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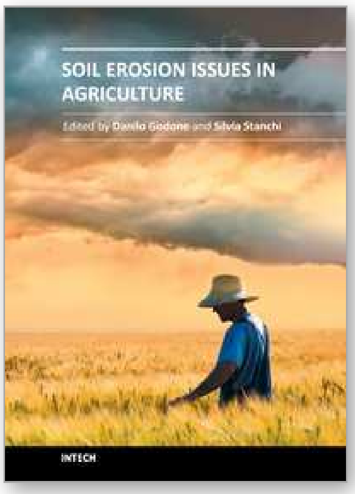

Soil Erosion Issues in Agriculture
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The book deals with several aspects of soil erosion, focusing on its connection with the agricultural world. Chaptersâ€™ topics are various, ranging from irrigation practices to soil nutrient, land use changes or tillage methodologies. The book is subdivided into fourteen chapters, sorted in four sections, grouping different facets of the topic: introductive case studies, erosion management in vineyards, soil erosion issue in dry environments, and erosion control practices. Certainly, due to the extent of the subject, the book is not a comprehensive collection of soil erosion studies, but it aims to supply a sound set of scientific works, concerning the topic. It analyzes different facets of the issue, with various methodologies, and offers a wide series of case studies, solutions, practices, or suggestions to properly face soil erosion and, moreover, may provide new ideas and starting points for future researches.

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