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RESEARCH PAPER

Effect of land use on soil quality in Rivers Nyando and Yala Catchments of Lake Victoria Basin, Western Kenya

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Abstract

Soil, as a major subsystem of land, is rapidly changing with time as a result of changes in its' environment or management. Periodic soil quality assessment is thus vital in evaluating agro-ecosystem sustainability, soil degradation, and identifying sustainable land management practices. This study assessed the impact of land use on soil quality in Rivers Nyando and Yala watersheds of Lake Victoria Basin, Western Kenya on three land use types namely: grazing fields, agricultural land and mixed farming. Surface (0-20cm) and subsurface (20-50cm) soil samples were collected at four different points within the 30mx30m plot and composite sample for each point packed in 4 different polythene bags for analysis. The soils were analyzed for soil organic carbon, nitrogen, phosphorus, pH, calcium, magnesium and potassium. Both descriptive and inferential statistics including Pearson Correlation Coefficient and Analysis of Variance (ANOVA) were carried out on the soil data. Findings showed that mean organic carbon and nitrogen levels varied significantly between land use types ($p<0.0001$). Mean potassium levels were significantly lower in grazing fields and higher in agricultural lands. The mean soil pH, phosphorus, calcium and magnesium were significantly higher in grazing fields compared to other two land use types. All parameters studied varied significantly between River Nyando and Yala catchments ($P<0.05$), with soils from River Nyando watershed having significantly higher mean phosphorus, calcium, magnesium and pH levels while those from River Yala catchment had significantly higher mean organic carbon, nitrogen and potassium levels. Soil organic carbon in composite samples showed significant negative correlation with pH ($r=-0.295^{**}$), magnesium ($r=-0.553$) and calcium ($r=-0.388$), but a positive correlation with potassium ($r=0.518^{**}$), phosphorus ($r=0.199^{*}$) and nitrogen ($r=0.804^{**}$) at $P<0.01$. Grazing fields had lower soil organic carbon and total nitrogen while agricultural land had lower soil exchangeable bases, pH and carbon to nitrogen ratio.

Key words: Lake Victoria basin, land use, land degradation, chemical properties

Introduction

Soil is a non-renewable natural resource, vital for optimal performance of key environmental, economic and social functions (FAO, 2015). Good quality soil contributes to five principal functions within a landscape: *i.e.* nutrient cycling; water-holding capacity; habitats and biodiversity; storing, filtering, buffering, and transforming compounds; and provision of physical stability and support (Koch *et al*., 2013). Therefore, high quality soils not only produce better crop yields, but also support natural ecosystems and enhance air and water quality (Griffiths *et al.,* 2010). Soil quality is thus closely connected to human and environmental health (Lal, 2015).

Unfortunately, soils across the world are under pressure of intensification and competing uses of forestry, urbanization, cropping and pasture (FAO, 2015). As such, land use types vary across the world; their fundamental purposes being provision of ecosystem services and benefits to meet human needs (Foley, 2005). Presently, soil quality degradation resulting from inappropriate land use is a worldwide problem that continues to threaten sustainable agricultural production systems world over (Somasundaram *et al*., 2013). Over the last 25 years, 24% of the global land area has suffered a dramatic decline in soil quality and productivity as a result of unsustainable land use management (Bringezu *et al*., 2014). A number of studies have demonstrated that indiscriminate use of land resource is mainly responsible for declining soil quality; reflected in the continuous reduction of soil organic matter, nutrients and alteration of soil physical structure (Yu *et al*., 2014; Hall *et al*., 2017; Abdalla *et al*., 2018).

Changes in a number of soil parameters have been reported in different land use types. Majaliwa *et al.* (2010) noted that land use practices and changes in soil management affect the distribution and supply of soil nutrients by directly altering soil properties and influencing biological transformations in the rooting zone. Don and Schumacher (2011) observed a 25% and 32% decrease in soil organic carbon stocks within 40 cm depth and 20 cm depth, respectively when tropical cropland was converted to grassland or fallow, while Zhu *et al*. (2012) reported lower soil organic matter (SOM) on arable land compared to forested land and natural grasslands. Likewise, Wang *et al*. (2012) reported high soil organic carbon (OC) and total nitrogen in natural secondary forests and grasslands compared to plantations and croplands.

Studies also show that soil biogeochemical and physical responses to livestock activities are regulated by complex and often interacting factors in pasture lands, among them: grazing practices (Steffens *et al*., 2008), plant community structure (Qu *et al*., 2016), climate and soil texture (Andrés *et al*., 2017). Excessive hoof trampling by grazing animals can also result in soil compaction, which causes a decrease in soil pore spaces, reduced infiltration and less plant available water (Pulido *et al.,* 2016). These impacts can subsequently impair soil structure (Steffens *et al*., 2008), decouple C and N cycles (Piñeiro *et al*., 2010), and reduce plant productivity. These studies imply that different landuse types can have effects on soil quality and fertility as confirmed by Rolando *et al*. (2018) in their study on landuse effects on soil fertility and nutrient cycling in the Peruvian high Andean Puna grasslands.

Land use-mediated soil quality degradation is pronounced in the tropics (Bustamante *et al*. 2016), where a combination of climate and poor soil management accelerates decomposition and soil nutrient loss. Africa in general and East Africa in particular are characterized by the accelerated deterioration of soil quality and stability (Tesfaye *et al.,* 2016; Lemenih *et al*., 2005), which has affected agricultural productivity, food security and the overall resilience of the socio-ecological system (Nyssen *et al*., 2004). Studies conducted in different parts of Kenya have painted a picture of declining crop productivity and diminishing pasture land - trends that have been attributed to factors such as growth in population density (Muyanga and Jayne, 2014) overgrazing and continuous cultivation without addition of external inputs leading to poor quality soil (Mugendi *et al*., 2007).

Studies have reported severe decline in soil quality within river basins resulting from increased soil erosion as a result of intensification of agricultural activities and other human activities (Sigstad *et al.*, 2002). As is the case with many river basins, Lake Victoria Basin (LVB) of Kenya has undergone accelerated soil erosion which is strongly linked to increase in agricultural activity (ICRAF, 2002). Large parcels of land have been converted from forest and shrub lands to agricultural and range lands through human activities and natural processes (ICRAF, 2002). The principal causes of soil quality degradation in the LVB catchment include land use changes such as deforestation of headwaters and overuse of extensive areas of fragile lands on both hill slopes and plains of Lake Victoria watershed for agricultural purposes (ICRAF, 2002).

Nyando and Yala River basins - the focus of this study, have faced unprecedented changes in land use over the years. Large parcels of land in the two basins has been converted into crop and pasture lands, with only small patches of bush land, forest and wetland still remaining (World Resources Institute *et al.,* 2007). As a result, these basins continue to experience severe soil erosion which contributes varying loads of sediment and nutrients into Lake Victoria. The average sediment transport capacity index of Rivers Nyando and Yala was reported to be around 0.3 and 0.14, respectively by the World Agroforestry Centre (ICRAF, 2002). Despite occupying a small proportion of LVB of Kenya, the sediment transport capacity index for the Nyando River basin was relatively higher compared to all the other rivers that drain into Lake Victoria (Walsh *et al*., 2004). It is estimated that approximately 61% of the Nyando River basin is a sediment source with an average erosion rate of 43 metric tons per hectare per annum (World Agroforestry Center, 2006).

A comparison between Yala and Nyando River basins showed 2-3 times higher turbidity levels in Nyando than Yala River between 2000 and 2002 (World Agroforestry Centre, 2006), an indication of soil fertility loss and subsequent soil quality degradation in their respective catchments. The Nyando River Basin thus exhibits some of the most severe problems of environmental degradation found anywhere in Kenya and is considered one of the most degraded of all river basins in the Kenyan portion of Lake Victoria Basin. In comparison, Yala River catchment is less degraded, making it perfect control for the study.

With continued severe erosion within the Yala and Nyando River basins, periodic monitoring of soil quality using indicators that interact synergistically is paramount.

The concept of soil quality is useful in assessing the changes and status of soil (Toth *et al.,* 2007). According to (Sione *et al*., 2017), a practical, effective and comprehensive soil quality evaluation must be inferred by measuring soil physical, chemical and biological indicators. Minimum datasets have been suggested that allow a detailed description of soil quality through the inclusion of soil chemical and physical indicators (Lal, 1998). This study assessed the effects of three land use types on a number of soil quality parameters in rivers Nyando and Yala catchments of lake Victoria Basin in Western Kenya.

Materials and Methods

Study area description

Lake Victoria, with a surface area of 68,000 km^2 and an adjoining catchment area of 184,400 km^2 is the world's second largest fresh water lake and the largest in the tropics. The lake is fed by a total of thirteen rivers namely: Nzoia, Yala, Nyando, Sondu Miriu, Gucha, Mara, Gurumeti, Mbalageti, Duma, Simiyu, Magoga, Isonga and Kagera (ICRAF, 2002). This study focused on the Nyando and Yala River Basins (Figure 1) that drain directly into Lake Victoria from the eastern side, with both their headwaters in the Mau forest complex of Kenya (Swallow *et al.,* 2008). Despite having the same source, the two river catchments differ with regard to geology, hydrology, gradient, precipitation episodes, human activities and extent of catchment degradation.

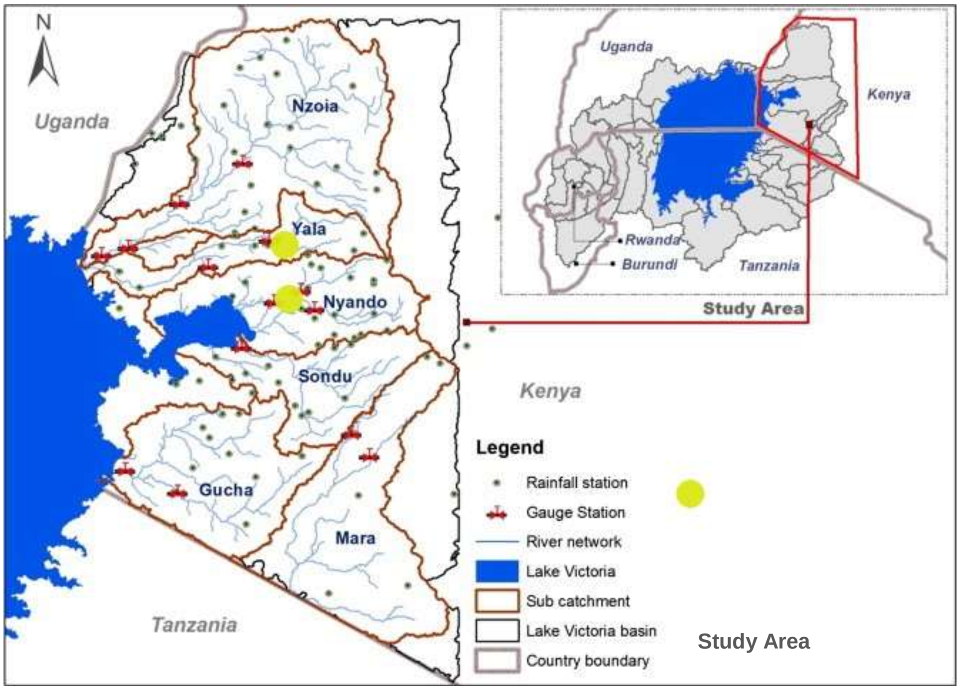

Figure 1: Map of Study Area showing position of Yala and Nyando River sub-catchments (Source: Nobert et al., 2014)

Nyando River Basin

The Nyando basin covers an area of about 3,587 km^2 and is bounded by latitude 0°10' N and 0°25' S and longitude 34°50' E and 35°50' E, within the scarps of the Kavirondo Gulf (KARI, 2006). Nyando basin has an altitude ranging between 1,184 m.a.s.l at the point of drainage into Lake Victoria to 3,000 m.a.s.l at the headwaters, and is drained by Nyando River with its major tributaries originating in the upland Nandi hills on the northern side and Mau escarpments on the eastern side (KARI, 2006). The river has an average percentage slope of 5 percent; which is the highest of all the rivers in the region. Based on data that spans six decades (1950 – 2000), Nyando River has a long-term average annual discharge of 18.0m^3/s; accounting for 2.3% of the surface inflow into Lake Victoria (Shepherd *et al*., 2000).

The basin experiences a bimodal rainfall pattern with long rains in March-May and short rains in September-November. Mean annual rainfall ranges from about 1,000 mm near Lake Victoria to about 1,600 mm in the highlands, with a minimum and maximum mean monthly rainfall of 72 mm and 243 mm respectively, while mean annual maximum and minimum temperature ranges between 25 - 30°C and 9 - 18°C respectively, (Muthusi *et al*., 2005).

Land use activities within the basin vary with altitude. On the upper reaches, agricultural activities involving subsistence farming of food crops, large cash crops and dairy farming are dominant, while the midland is dominated by a mixture of smallholder farms (with maize, beans and some coffee, bananas, sweet potatoes and dairy) and large scale commercial farms (mostly sugar cane) that often alternate with pasture lands. The flood prone lowland area is dominated by pasture lands but also used for subsistence production of maize, beans, sorghum and commercial production of sugar cane and rice. A large section of the upper reaches has suffered extensive deforestation in the past to create room for human settlement and farming activities, exerting severe environmental strain on the mid and lower catchment areas (Verchot *et al*., 2008).

Soils with high silt and clay content consequent of Ferrasols, Nitisols, Cambisols, and Acricsols are predominant in the upland areas, while midland areas are characterized by gleyic/orthic luvisols soils that are partly over petrophlinthite (Jaetzold and Schimdt, 1983). The lowland area is dominated by Luvisol, Vertisol, Planosol, Cambisol, and Solonetz. Generally, these soils are well drained to moderately drained sandy clay loams (Jaetzold and Schimdt, 1983). With a human population of about 1,100,100 people as of 2009 (KNBS, 2009), within its basin, Nyando River has been identified as being among the most polluted drainage basins on the Kenyan side of Lake Victoria (Shepherd *et al*., 2000). Land degradation is widespread with significant levels of erosion estimated to have affected 61.1% of the basin at an average of 43.5 tonnes per hectare. Severe gully erosion in the lower reaches is the most visible sign of land degradation (World Agroforestry Centre, 2006). Soil erosion and sedimentation have become increasingly severe over the last 60-100 years (ICRAF, 2002).

Yala River Basin

The Yala River Basin covers an area of 3,351 km^2 with an elevation ranging from 1200 m.a.s.l. in the lowlands to 2200 m.a.s.l. in the highlands. The 219 km long Yala River originates from Nandi Escarpment water tower and traverses Kakamega and Siaya counties before discharging into Lake Victoria at Winam Gulf. The river has a long-term average annual discharge (based on data from 1950 to 2000) of 37.6 m^3 per second, accounting for about 4.8% of the surface inflow into Lake Victoria (Otiende, 2009). Average annual rainfall is about 850 mm in the large flat area near Lake Victoria and up to 2,000 mm in the highlands. Rainfall is received during two rainy seasons: *i.e.* short and long rainy seasons (Otiende, 2009).

The common landuse types within the upper Yala River basin are human settlements, tea and coffee plantation and crop agriculture with pockets of individual grazing plots. The mid-altitude areas are dominated by smallholder farms (with maize, beans and some coffee, tea, bananas, sweet potatoes and dairy), while lowlands comprise of wetlands that cover approximately 17,500 ha and contains three freshwater lakes; Kanyaboli, Sare, and Namboyo (Okeyo–Owuor *et al.,* 2012).

Soil type in the upland and midland catchment are well drained, deep, dark-reddish-brown humic Nitisols owing to the variations in the atmospheric climate and pedoclimate, while the lowlands have well to moderately drained sandy clay loams just before the swamp (FAO, 1997). A study in the Yala basin by Awiti *et al.* (2007) showed continual decline in land productivity and soil condition in agricultural lands around the Kakamega Forest over the last 60 years with to potential to affect over 2 million people residing within the basin.

Study design

This study adopted a cross-sectional study design. Ground sampling locations of the River Nyando and River Yala catchments were selected using spatially stratified systematic random sampling approach into blocks (10 Km x 10 Km). The blocks were selected based on their geographical position on the landscape representing headwater, midslope and lowland. One block was identified in each of the river catchment and in each block, 15 clusters of 1 Km x 1 Km were randomly identified. Within the cluster, 13 pixels of 30m x 30m were identified systematically and each was considered as a plot. From each pixel, four sampling points were identified and sampled.

Soil sample collection

A total of 3,216 soil samples for soil analysis were collected; *i.e.* 1679 from Rivers Nyando watershed and 1537 form River Yala watershed using a soil auger. From each pixel, surface (0-20 cm) and subsurface (20-50 cm) soil samples were collected from four corners within the 30 m x 30 m plot and composite soil sample packed in polythene bags and sealed with rubber band, yielding 4 samples per plot for laboratory analysis. Each polythene bag was identified by the sample site identification code. Sampling was conducted over a period of 9 months, from February to October.

Soil sample processing

Approximately one kilogram of composite soil sample from each depth was taken and stored in plastic bags. The soil was air-dried at room temperature and carefully pounded with pestle and mortar, homogenized and passed through a 2 mm sieve before laboratory analysis.

Determination of soil spectral reflectance signatures

Soil spectral reflectance signatures was achieved by scanning the processed soil samples with FieldSpecTM FR spectroradiometer (Figure 2), under laboratory conditions, at wavelengths of between 350 nm to 2500 nm, with a spectral resolution of less than 0.03 μm (Analytical Spectral Devices Inc., 1997). The procedure adopted for use of the equipment in scanning are those reported in Shepherd and Walsh (2002). Precisely, soil samples of 2 mm thickness were placed into borosilicate Duran glass Petri dishes with optimal optical characteristics. The Petri dishes were placed on a mug light equipped with a Tungsten Quartz Halogen light source (Analytical Spectral Devices Inc., 1997). Spectral reflectance readings were collected through the bottom of the Petri dishes using a Field-Spec PRO FR spectro-radiometer (Analytical Spectral Devices, Boulder Inc., 1997). Every sample was measured twice, with the sample rotated by 90 degrees for the second measurement. The two measurements were averaged to minimize light scatter effects from uneven particle size distribution on the Petri dish floor. The intensity of reflected light, which is plotted as a function of wavelength gave distinctive patterns known as spectral reflectance signatures. The signatures were interpreted to generate data presented in tables and texts.

Figure 2: Field SpecTM FR spectroradiometer

Data analysis

Three landuse types: crop lands, grazing lands and a mixture of crop land and grazing lands were studied. The landuse types and and rivers catchments were the independent variables and soil parameters (SOC, pH, phosphorus, nitrogen, magnesium, calcium and potassium) were dependent variables. Statistical differences between soil quality indicators and land use types or soil depth were tested using analysis of variance (ANOVA) following the general linear model (GLM) procedure at $P \leq 0.05$. Duncan Multiple Range Test (DMRT) was used for mean separation when the analysis of variance showed statistically significant differences. Correlation matrices among soil quality indicators were based on Pearson correlation coefficients with levels of significance at $P < 0.05$, $P < 0.01$ and $P < 0.001$. The coefficient of variance (CV) was used to express the dispersion and difference of each soil quality indicator.

Results

Based on analysis of soil indicators, the levels of soil organic carbon, nitrogen, pH, phosphorus and exchangeable cations in soil samples obtained from agricultural land, mixed farming plots and grazing fields varied considerably. One-way ANOVA showed highly significant differences in all the soil indicators studied among landuse types ($p<0.0001$) with the post hoc test (DMRT) establishing significant difference in all soil indicators - except nitrogen, among the three landuse types. Nitrogen levels differed significantly between agricultural land and the other two land use types. Consolidated soil samples drawn from the two river catchments and obtained from grazing fields had significantly higher mean pH, phosphorus, calcium and magnesium levels, compared to mixed farming and agricultural lands, which had the least mean pH, phosphorus, calcium and magnesium. However, potassium, carbon and nitrogen were highest in soil samples obtained from agricultural lands and lowest in those obtained from grazing fields (Table 1).

Table 1: Pooled mean soil organic carbon, nitrogen, phosphorus exchangeable cations and pH among the land uses drawn from both catchments

Element/Land use	Agricultural land (N=2237)	Mixed farming (N=324)	Grazing fields (N=655)	F-Value
Carbon (mg/Kg)	14.383^{A}	9.650^{B}	6.559^{C}	888.3
Nitrogen (mg/Kg)	1.567^{A}	1.272^{B}	1.244^{B}	106.4
pH	5.4336^{A}	6.5512 ^{B}	6.7440^{C}	1005.6
Phosphorus (mg/Kg)	5.4349^{A}	11.5611^{B}	16.2375^{C}	658.04
Potassium(mg/Kg)	0.3407^{A}	0.1855^{B}	0.1333^{C}	449.2
Calcium(mg/Kg)	4.6004^{A}	19.5802^{B}	46.9848^{C}	276.3
Magnesium(mg/Kg)	1.3082^{A}	4.4155^{B}	5.1829^{C}	1766.5

Means with the same superscript within the row are not significantly different (DMRT), one way ANOVA, $P<0.05$

All soil properties (organic carbon, nitrogen, phosphorus, calcium, magnesium, potassium and pH) analysed in consolidated surface and sub-surface soil samples (composite samples) across the two catchments varied significantly between River Nyando and Yala catchments ($P<0.05$). Generally, Soil samples from Nyando River catchment had significantly higher mean phosphorus (14.69 mg/kg), calcium (37.94 mg/kg), magnesium (4.93 mg/kg) and pH (6.68) while River Yala catchment had significantly higher mean values of organic carbon (14.4mg/Kg), nitrogen (1.56mg/Kg) and potassium (0.34 mg/kg) (Table 2).

Table 2: The dynamics of soil organic carbon, nitrogen, phosphorus, calcium, magnesium, potassium and pH in composite soil samples from rivers Nyando and Yala watersheds

Nutrients	Nyando (N=1679)	Yala (N=1537)	F value
Organic Carbon (mg/Kg)	7.6^{A}	14.4^{B}	1588.8
Nitrogen (mg/Kg)	1.3^{A}	1.56^{B}	212.3
Phosphorus mg/Kg	14.69^{A}	5.43^{B}	106.9
Calcium mg/Kg	37.94 ^{A}	4.6^{B}	435.6
Magnesium mg/Kg	4.93^{A}	1.31^{B}	3407.8
Potassium (mg/Kg)	0.151^{A}	0.34^{B}	869.4
pH	6.68^{A}	5.43^{B}	1983

Means with the different superscript within the row are significantly different (DMRT) one way ANOVA, $P<0.05$.

Some soil parameters were significantly correlated. Soil organic carbon showed significant negative correlation with soil pH (r=-0.295**), magnesium (r=-0.553) and calcium (r=-0.388) but it registered a significant positive correlation with potassium (r=0.518**), phosphorus (r=0.199*) and nitrogen r=0.804**) at $P<0.01$. Similar correlations both in magnitude and directions were observed between nitrogen and exchangeable cations (Ca, K, and Mg) and soil pH (Table 3).

Table 3: Correlations among soil organic Carbon, Nitrogen, exchangeable bases and Ph

Element	Calcium	Potassium	Phosphorus	pH	Magnesium	Nitrogen
Carbon	-0.388**	0.518**	0.199**	-0.295**	-0.553**	0.804**
Nitrogen	-0.098**	0.393**	0.341**	-0.011*	-0.192**	-
Potassium	-0.303**	-	0.017	-0.151**	-0.462**	0.393**

** Correlation is significant at the 0.01 level (2-tailed)

The mean C:N ratio recorded in this study was 8.4:1, however, the highest ratio observed for agricultural land, mixed farming and grazing land was 9.2:1, 7.6:1 and 5.3:1, respectively.

Discussion

Soil organic carbon, nitrogen, exchangeable bases and pH among land uses

This study established significant differences in soil quality indicators between different land use types in the two catchments studied. For instance, significantly higher levels of soil organic carbon and nitrogen were observed in composite soil samples obtained from agricultural lands compared to those obtained from grazing fields and mixed farming plots. This could be attributed to soil management practices like use of fertilizers and differences in soil erosivity and biomass return following crop harvest in agricultural lands. On the contrary, low soil carbon in grazing fields could be attributed to overgrazing and soil erosion. Conant *et al.* (2002) demonstrated that grazing management drove change in soil carbon stocks by influencing the balance between what goes into the soil (inputs) and what comes out of it (outputs).

Studies show that soil erosion and the subsequent transport of sediments by rivers represent a key pathway for soil carbon loss (Lal, 2010), which has a profound effect on the carbon budget of terrestrial ecosystems (Li *et al.,* 2018; Wang *et al*., 2019). Dlugoß *et al*. (2012) in their study on carbon fluxes in a small agricultural catchment established that SOC depletion took place at eroding sites while SOC accumulation took place at depositional sites. Being a selective process, soil erosion preferentially transfers fine and light materials, which are typically enriched in SOC relative to the bulk soil (Wairiu and Lal, 2003). This process can lead to carbon loss in the eroding profiles and enrichment of the labile carbon fraction in the depositional profiles especially in areas prone to soil erosion such as grazing fields.

A comparison between the two river catchments in the current study revealed high organic carbon, nitrogen and low pH in soil samples obtained from River Yala catchment compared to Nyando River catchment. This could be attributed to the fact that over 90% of the Yala River catchment is dominated by agricultural crops which could be contributing substantial amounts of biomass return to the soil as opposed to River Nyando catchment; whose dominant landuse was grazing fields. Nevertheless, in the face of increased landuse intensification to meet global demand for food, water and energy, soil management to sustain and enhance carbon stocks is of utmost importance if this valuable resource is to be conserved for future generations (Foresight, 2011).

Soil enhancement to improve its productivity though application of nitrogen and phosphorus based fertilizers is the most common soil management strategy practiced within Nyando and Yala River catchments by farmers (Raburu and Okeyo-Owuor, 2005). The use of fertilizer contributes to relatively higher nitrogen and phosphorus levels in agricultural land compared to grazing fields. Nevertheless, the relatively low phosphorus, exchangeable calcium and exchangeable magnesium observed in agricultural lands in River Yala watershed in the current study could have been as a result of removal by crops' edible parts and plant residues. Hossain (2006), concurs that nutrient removal by the harvested portion of agricultural crops is the primary pathway through which soil loose nutrients.

Heavy application of chemical fertilizers especially in the Yala and Nyando catchment sugar belt areas by large scale farmers could have contributed to the high soil acidity as reflected by low pH levels in the current study. Besides, weak acids are often produced in soils when plant residues and organic matter decompose. In addition, calcium, magnesium and phosphorus which are essential nutrients for plant growth can have acidifying effects on soil when they are removed from the soil through crop harvest (Jensen, 2010). This was demonstrated in the current study by the high soil acidity (low pH) recorded in agricultural lands compared to mixed farming land and grazing fields.

Soil organic carbon, nitrogen, phosphorus, exchangeable bases and pH correlations

A positive correlation was observed between carbon and nitrogen levels in soil samples in the current study. This is consistent with the carbon to nitrogen ratio reported by many researchers among them Swangjang (2015). Sakin *et al.* (2010) observed that soil organic carbon reservoir in tropical ecosystem is an important component of the terrestrial system and that carbon to nitrogen ratio (C:N) is an indicator of net N mineralization and accumulation in soils. Deng *et al.* (2013) pointed out that the greatest SOM mineralization occurred at substrate C:N ratio of 25, while at ratio less than 20, mineral N was released in the early process of decomposition. The authors further emphasized that the dividing line between immobilization and N release is about 20:1, with most natural plant-soil systems having carbon to nitrogen ratios of about 20:1. Because the composition of most woody vegetation is chemically similar, the relationship between carbon, nitrogen and phosphorus is remarkably stable between different environments (Swangjang, 2015).

Nevertheless, the high carbon to nitrogen ratio observed in soils under agricultural land as opposed to mixed farming land and grazing fields in the current study could be attributed to removal of nitrogen through plant uptake and subsequent removal through harvest as well as use of nitrogen as source of energy for decomposition among the microbes. All in all, SOM is important in soil protection as it promotes resistance to erosion of soils and helps regulate flooding by increasing infiltration, reducing runoff and slowing water movement from upland to lowland areas (Batjes, 2016). It also reduces the release of agrochemicals, pathogens and contaminants to the environment by aiding their retention and decomposition (Burauel and Baβmann, 2005). Studies also show that while soil organic matter (SOM) is primarily carbon, it also contains essential nutrients used for plant growth; such as nitrogen, phosphorus, sulphur and micronutrients (Brussaard *et al*., 2007). However, the rate of SOM decomposition and turnover mainly depends upon the interplay between soil biota, temperature, moisture and a soil's chemical and physical composition (Taylor *et al*., 2009).

In the current study, a negative correlation was observed between potassium and calcium, magnesium and soil pH. This can be attributed to excess potassium in the soil. Studies indicate that K, Ca and Mg uptake do not only depend on their concentrations in the soil, but also on their ratios (Weih *et al*., 2011). An excess application of one nutrient may induce deficiency of the others. For instance, K, Ca and Mg strongly interfere with each other during the uptake process (Nguyen *et al.,* 2017). High Mg concentration in soil inhibits the uptake of K and Ca, while high concentration of potassium in nutrient solution inhibits the uptake of Ca and Mg (Nguyen *et al*., 2017).

Soil pH is a very important chemical property of soil with most plant nutrients being available at slightly acidic to slightly alkaline soil (pH 6.5 to 7.5). In the current study, pH was generally acidic ranging between 5.43 in Yala River to 6.68 in Nyando River, while in the different land use types, pH ranged from 5.4 in agricultural lands to 6.5 and 6.7 in mixed farming and grazing fields respectively. Studies show that the availability of macronutrients is highly dependent on the soil pH (Khadka *et al*., 2016). For instance, a number of plant nutrients are unavailable at extremely acidic or extremely alkaline soils due to the different reactions in the soil which fix the nutrients and transform them to the state that is unavailable for the plants (Jiang *et al*., 2017). All in all, nitrogen, potassium, calcium, magnesium and sulfur are more available within soil pH 6.5 to 8, while phosphorus is most available within soil pH 5.5 to 7.5 (McCauley *et al*., 2017).

Conclusion

The study findings indicate that different landuse types affect soil properties at different scales. Livestock grazing reduces soil organic carbon and nitrogen through reduced organic matter input, while crop farming in agricultural lands lowers soil exchangeable bases, which in turn lower soil pH. Agricultural practices can also elevate soil carbon to nitrogen ratio through nitrogen leaching and excess microorganism decomposition on landscape compared to grazing field where the land was intact. Mixed farming lands where livestock grazing alternated with crop agriculture had intermediate soil properties. It was therefore noted that livestock grazing can affect the surface chemical properties of soils thus changing the natural process, hence lowers soil functions and qualities. Generally, soils from River Nyando catchment were severely degraded compared to those from River Yala catchment.

Recommendation

Soil organic matter plays a very important role in soil productivity since it controls soil cation exchange capacity; a process that supports vegetation growth. It is therefore necessary for farmers and other stakeholders to ensure that land within the catchments have adequate ground vegetation cover most of the year through planting of ground cover crops to check on soil erosion. Practicing agro forestry within crop farms should also be encouraged among farmers to increase organic carbon input. Since some areas especially in River Nyando catchment are extremely degraded by sheet erosion and there is possibility that these areas might have lost most of seeds from the soil seed bank, there is need for farmers in the area to consider reseeding their farms with grass and ground cover plant seeds. This will enhance above ground vegetation cover that ensures organic carbon input and soil surface protection are in place to improve soil bulk density. Farmers should adopt the use of organic manure as source of soil fertility and their capacity be built on the merits of use of such farm inputs. Those farmers who do not have livestock; which are considered to be the main source of organic manure in rural areas, can establish small compost pits at home. Organic manure will help improve soil fertility and structure; factors that govern soil bulk density, saturated hydraulic conductivity and soil erosion. All these combined, have a bearing on the ecosystem structure and functions restoration.

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