ASSESSMENT OF SOIL QUALITY UNDER DIFFERENT GRAZING INTENSITIES IN THE RIMA RIVER FLOODPLAIN, KWARE LOCAL GOVERNMENT AREA OF SOKOTO STATE, NIGERIA

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ABSTRACT

The Rima River floodplain is reportedly overgrazed but effects of grazing on soil quality is yet to be investigated. Thus, the study examined soil quality across grazing intensities. Three juxtaposed grazing intensities namely Dense Grassland (Low), Grassy Fallow (Medium) and Grazed Open Grassland (High) were identified based on an existing Land-Use/Land-Cover (LULC) map. From each treatment, soil sampling was carried out at 15 randomly selected 10m *10m quadrats. Also, 4 subsamples were augered to 0-30cm depth at the corners of the quadrat after which the subsamples were bulked and homogenized. Four bulk density (δB) subsamples were also taken at the sides of the quadrat using a core sampler, the readings of which were averaged for the quadrat after the laboratory test. Samples were analyzed using standard laboratory procedures. Descriptive statistics of soil properties were calculated, while ANOVA was used to determine grazing effect on soil quality. Duncan Multiple Range Test (DMRT) was used for a post-hoc test on the treatments for each of the soil properties. Results showed that Soil Organic Carbon (SOC), Total Nitrogen (TN), Available Phosphorous (P), Potassium (K), Cation Exchange Capacity (CEC) and δB significantly differed ($p<0.05$) across grazing intensities with exception of pH. All properties decreased with increasing grazing intensity except δB which increased with increasing grazing intensity. pH did not exhibit a predictable pattern across treatments. The study concluded that grazing negatively affected the soil quality of the Rima river floodplain. Establishment of grazing areas within the floodplain was recommended for sustainable soil management.

Key words: Floodplain, Grazing, Rima, Soil quality, Sokoto

INTRODUCTION

It is estimated that about 70% of the world's agricultural land is grazing land, supporting about 360 million cattle and over 600 million sheep and goats (Abdalla et al., 2018). It is also estimated that more than 23% of the world’s grassland is degraded due to overgrazing (Zhao et al., 2017). Thus, there is the fear as to the sustainability of grazed ecosystems in the 21st century (Lal, 2001; Tarin et al., 2016; Wang et al., 2018).

Instances of negative impact of grazing on soil quality abound in the literature. For example, Hiernaux et al. (1999) studied the effects of livestock grazing on the physical and chemical properties of the sandy soils in the Sadore rangelands of Niger and found out that grazing decreased the soil pH, organic carbon, nitrogen and phosphorous. Li et al. (2011), while considering different grazing treatments on the Tibetan Plateau, observed declines in vegetation, soil carbon and nitrogen with increases in grazing intensity. The effect of grazing exclusion on soil quality has been demonstrated at different scales, regions and seasons. Results from such studies have shown grassland restoration, vegetation recovery and improved soil quality (Liu et al., 2017; Boughton, Bohlen and Maki, 2018).

Positive impacts of grazing on soil quality have also been reported in many studies. For example, Flores and Tracy (2012) and Tarin et al. (2016) have shown that winter hay feeding under good management systems could be of beneficial increases in phosphorous, potassium, and soil organic matter. Medina-Roldan, Paz-Ferriro and Bardgett (2012) have demonstrated that grazing enhances soil microbial activities and nutrient cycling. The effects of mixed grazing of sheep and goats on physical and chemical properties of sandy soil in Sadore rangelands of Niger were monitored by Hiernaux et al. (1999). Results showed that infiltration slightly increased under moderate grazing, but decreased due to high stocking rate, resulting in increase in bulk density. Similarly, Zhao et al. (2017) assessed grazing intensity influence on soil microbial communities and implications for soil respiration. The study concluded that light and moderate grazing intensities were helpful for soil microbial, bacterial and fungal communities. This suggests that moderate grazing could be beneficial to the soil.

Effect of grazing on soil quality appears inconsistent as the foregoing suggest that grazing could be beneficial or detrimental. However, studies have reported that the degree of grazing impact on soil is a function of many factors. In the submission of Zhao et al. (2017), different grazing intensities and different environmental conditions can generate different effects on soil quality. Cropp, Moroz and Norbury (2017) argued that grazing effect can depend on the grazers and grazing strategies. Zhang et al. (2018) reported that effect of grazing can also relate to the ability of plants to cope with changes in their environment due to grazing. The nature of land cover in terms of foliage, water availability and topography can create spatially heterogeneous effects of grazing (Wang et al., 2014; Eniolorunda, Mashi and Nsofor, 2016).

The Sokoto-Rima floodplain is ecologically and economically strategic to the survival of the vast agrarian populations living in the surrounding settlements (Swindell, 1986; Eniolorunda, Mashi and Nsofor, 2016). Although the floodplain is reportedly overgrazed (Swindell, 1986; Adeniyi, 1993), effect of grazing on its soil quality is yet to be investigated. In this study, it was hypothesized that soil properties under different grazing intensities in the Sokoto-Rima floodplain did not differ. The objectives include examining the quality of soil variables in each grazing treatment and comparing them across the treatments.

THE STUDY AREA

The study was conducted at a site covering 84ha in the upper part of the Rima River floodplain in Kware LGA of Sokoto State, North-western Nigeria (Figure 1). The floodplain ranges between 217- 410m above sea level (ASL) and has a width range of 2-4km (Adeniyi, 1993; Ifabiyi and Eniolorunda, 2012). The floodplain lies on the Illumeden basin - a sedimentary formation - extending from Mali through Niger to Sokoto. It is characterized by chalky limestones, calcareous mudstones and clay shales (Ifabiyi and Eniolorunda, 2012). The area records an annual rainfall of about 600mm which lasts between May/June and September/October. Average daily temperature is 36°C and maximum temperature could reach 44°C in the middle of the dry season (March) (Ifabiyi and Eniolorunda, 2012). Evapotranspiration reaches 10.06 mm/day in the middle of the dry season (March) (Akpootu and Iliyasu, 2017). Low rainfall and high evapotranspiration restrict agricultural activities in the dry season to the floodplain (Adeniyi, 1993). Thus, dams were constructed upstream in the 1980s to ensure continuous supply of water for dry season agriculture.

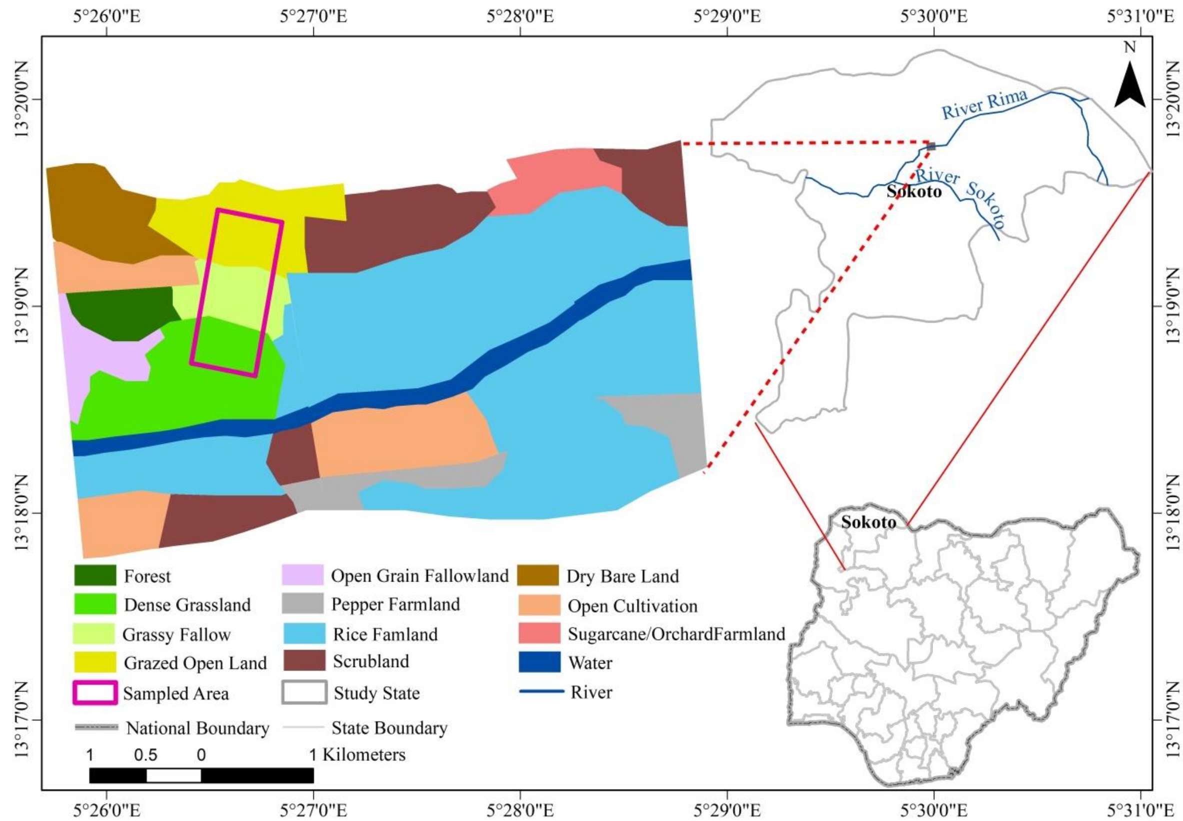

Figure 1: Study Area.
Source: Adapted and modified from Eniolorunda, Mashi and Nsofor (2016)

MATERIALS AND METHODS

Selection of Study Sites

Three closely juxtaposed Land Use Land Cover (LULC) types were used for this study namely: Dense Grassland (DG), Grassy Fallow (GF) and Grazed Open Grassland (GOG), corresponding to Low, Moderate and High Intensity Grazing LULC types. The classes were adapted from Eniolorunda, Mashi and Nsofor (2016). Closeness of the selected classes guaranteed same physiographic conditions (Yuksek et al., 2009; Flores and Tracy, 2012). The DG is mainly composed of luxuriant grasses which are about 3m in height. It is commonly interspersed with shrubs, and such covers are left to fallow for two farming seasons, thereby providing grasses for cattle to graze (Eniolorunda, Mashi and Nsofor, 2016). Fallowing is due to the less wetness in that part during the dry season. Common grasses are *Stachytarpheta indica* (devil's coach whip), *Urelytrum giganteum* (giant grass), *Pennisetum purpureum* (elephant grass), *Imperata cylindrica* (spear-grass), *Commelina benghalensis* (benghal dayflower), among others. Commonest shrub is the *Mimosa pigra* (giant sensitive tree). Due to the thorny nature of the species and the density of the grasses, the area is difficult to penetrate by animals. Hence, grazing is comparatively low.

The GF represents areas that are left to fallow for a farming season. The area is wetter, and it is more grazed compared to DG. Plant residues form parts of animal feed, and in some parts, few stands of *Pennisetum glaucum* (millet), *Sorghum bicolor* (guinea corn) and *Zea mays* (maize) are noticed, serving as vestiges of previously cultivated crops. Grasses usually measure below 1m on the ground as they are under cattle grazing. Commonest species are *Oryza perennis* (wild rice), *Urelytrum giganteum* (giant grass), *Imperata cylindrical* (spear-grass), *Commelina benghalensis* (benghal dayflower), among others. The GOG is highly grazed, mainly serving as grazing corridor for large numbers of cattle that move in different herds. Due to high level of grazing and animal traffic, bare paths are sometimes created. Major grass species here is *Axonopus fissifolius* (carpet grass).

Soil Sampling and Analysis

Fifteen 10m by 10m quadrats randomly located were used for soil sampling from each grazing area. In each quadrat, four subsamples were collected at the corners of the quadrat and bulked as one sample. Thus, overall, 45 bulked samples were collected for the three LULC types. Sampling was carried out with a soil auger to a depth of 0-30cm. A core sampler was used to collect four surface samples from each quadrat for soil bulk density determination.

Collected samples were air-dried for 48hours, crushed and sieved with a 2-mm mesh. Soil pH was determined in water (1:1 soil-water ratio) and measured with a pH meter as described by Vallejo et al. (2012), while Soil Organic Carbon (SOC) was determined using the Walkley-Black method as used by Noma et al. (2011). Total Nitrogen (TN) was determined using Macro Kjeldahl method as described by Omar (2011), while available Phosporus (P) was determined by a method described by Yakubu et al. (2008). Potassium (K) was determined by flame photometer, while Cation Exchange Capacity (CEC) was determined by ammonium saturation method as described by Noma et al. (2011). Available phosphorous was determined using a spectrophotometer as described by Ibrahim (2011). Soil bulk density was determined by method used by

The data from the laboratory were analyzed using descriptive statistics such as mean and standard deviation. The One-way Analysis of Variance (ANOVA) was used to test the effect of grazing on each soil property using the reported P-value. Duncan Multiple Range Test (DMRT) was used to carry out a post-hoc test for each of the soil properties across the treatments.

RESULTS AND DISCUSSION

Table 1 summarizes the relationship between grazing intensities and soil properties over the study area.

Table 1: Statistics of Soil Properties across Grazing Intensities

Soil Property	Land Use/Cover (Grazing Intensity)			F-Test	P-Value
	Dense Grassland (DG) (Low)	Grassy Fallow (GF) (Medium)	Grazed Open Grassland (GOG) (High)		
pH	6.17±0.04[2]	5.78±0.07 [1]	6.16±0.05 [2]	13.32	0.000
Total N (g/kg)	1.07±0.03[2]	0.92±0.03[1]	0.91±0.05[1]	8.77	0.000
Avail. P (mg/kg)	1.25±0.48[3]	0.87±0.21[2]	0.79±0.27[1]	7.52	0.003
Exch. K (cmol(+)/kg)	0.94±0.16[2]	0.91±0.23[1]	0.90±0.33[1]	46.69	0.000
SOC (g/kg)	6.66±0.04[3]	6.24±0.06[2]	5.48±0.11[1]	50.52	0.000
CEC cmol(+)/kg	10.38±0.45[3]	7.97±0.58[2]	6.03±0.56[1]	37.54	0.000
Bulk Density (g/cm^3)	1.38±0.02[1]	1.48±0.03[2]	1.78±0.04[3]	38.94	0.000

Superscripts are the Duncan's post-hoc test results. Means with the same superscript along the same row are not significantly different (P > 0.05).
Source: Author's Field Data Collection

Soil pH

Table 1 shows that for the three grazing areas, soil pH is moderately to slightly acid, ranging between 5.78 and 6.17. Table 1 further shows that between the Low and High treatments, pH concentrations do not differ significantly (p>0.05). However, the observed value in the Medium treatment is significantly different (p<0.05) from those of the Low and High treatments. Since the p value of F-test is less than 0.05, it can be said that grazing has effect on pH in the study area. Hiernaux et al. (1999) studied the effects of livestock grazing on the physical and chemical properties of the sandy soils in the Sadore rangelands of Niger and found out that grazing decreased soil pH. Tamartash, Jalilvand and Tatian (2007), in testing the effects of grazing on chemical soil properties and vegetation cover in some Iranian rangelands, observed reduction in the soil pH due to grazing.

Previous studies have reported slight soil acidity of the floodplain (Ibrahim, 2011; Noma, 2011). Acidity may be attributable to production of H^+ ions and organic acids by soil microbes during organic matter (OM) decomposition (Yakubu et al., 2008; Rao, 2012; Brady and Weil, 2013). Acidity is capable of limiting the availability of macro nutrients such as Ca, K, Mg, N and P in the soil (Brady and Weil, 2013). It can also result in the toxicity of micronutrients such as Al, Co, Cu, Fe, Mn and Zn (Abubakari et al., 2012); hence, crop productivity may be affected.

Soil Total Nitrogen (TN)

The values of TN are high in concentration and decrease with increasing grazing intensity. DG has a value of 1.07g/Kg, while GF has a concentration of 0.92 g/kg. The GOG has a concentration of 0.91g/kg which is not significantly different (p>0.05) from the mean concentration in GF. However, the obtained value in DG significantly differs (p<0.05) from those captured in GF and GOG. Notwithstanding, the P-value of F-test (P<0.05) confirms that grazing has a significant effect on TN. Studies have shown that TN concentration is directly related to the amount of soil organic matter (Noma and Gabasawa, 2005; Ibrahim, 2011) because TN is an integral part of plant for building plant's protein (Foth 1990; Flores and Tracy, 2012). Thus, the removal of plant cover due to grazing can result in soil TN loss. He et al. (2011) found that TN storage in soil layers decreased linearly with increasing stocking rate and grazing intensity. Similarly, An and Li (2015) discovered that SOC and total TN contents decreased with grazing intensity in a semi-arid desert grassland of China, attributing decrease in plant aboveground vegetation and changes in soil properties under grazing.

While TN and SOC concentrations in this study both have same patterns, the low ratings of SOC across the treatments appear insufficient to explain the high TN concentrations. The very high values of TN as obtained are likely a consequence of high level of nitrogenous fertilizer application in the floodplain. Babalola et al. (2011) obtained an average TN value higher than the critical limit in a wetland in Ado Ekiti, while Makoi and Ndakidemi (2008) reported 4.5g/kg in an irrigation scheme in Tanzania. It thus appears presumable that high TN concentrations are characteristic of cultivated wetlands.

Soil Available Phosphorous

Table 1 indicates that Available P is highest in the Low grazing area with 1.25mg/kg, while it is 0.87mg/kg in the Medium treatment. About 0.79mg/kg is the value obtained from the High grazing intensity area. Table 1 further shows that these values differ significantly ($p<0.05$) from one another, indicating that grazing has effect on Available Phosphorous. Although P concentrations reduced with increasing grazing intensities, all obtained values are low in terms of fertility. The earth's crust contains about 0.1% P, existing in mineral form mostly as Fluora-patite ($Ca_{10} (P0_4)_6F_2$) (Foth, 1990). In spite of its abundance, there is still deficiency in supply to plants (Sander and Penas, 2006). P is a non-substitutable, non-renewable and geographically restricted but essential resource for food production (Chowdhury, Moore and Weatherley, 2018).

The surest ways of P inflow into the soil are through weathering and erosion, addition of inorganic phosphate fertilizers and organic waste. Although Phosphate fertilizers are used in the floodplain, the grazing areas could only be enriched with P through addition of organic waste. Thus because of the higher vegetation density in the Low Grazing (Dense Grassland) treatment, high P concentration is retained than in the higher grazing intensities. Although animal dungs may be more in the treatments with higher grazing intensities which could increase P concentration (Baron et al., 2001; Chowdhury et al., 2018), it is important to note that areas of high grazing intensities are characterised by higher rates of leaching, surface runoff and erosion (Dougherty et al., 2007; Ho et al., 2018). Haan et al. (2006) argued that management practices that reduce the total volume of surface runoff and encourage infiltration will reduce the potential for sediment and P losses. Thus it is possible that all or some of these could be responsible for the observed lower values of P in this study.

Soil Exchangeable Potassium (K)

Exchangeable K values recorded are 0.94cmol(+)/kg, 0.91cmol(+)/kg and 0.90cmol (+)/kg respectively for Low, Medium and High grazing intensities. In terms of fertility, the observed K concentrations are very high. High K concentration is characteristic of arid and semi-arid environments as they have sufficient weatherable potassium contained minerals to supply the soil (Brady and Weil, 2013). Also the application of potassium rich fertilizers may partly be responsible. In spite of high K concentrations in all the treatments, result of post-hoc test shows that there is significant difference ($p<0.05$) between the Low grazing intensity and the higher grazing intensities, while no significant difference ($p>0.05$) exists in the observed values between the higher intensities. It is clear from Table 1 that the higher the grazing intensity, the lower the K value in the study area. It is also clear from Table 1 that grazing has impacted on the soil exchangeable K ($P<0.05$). Impact of grazing on soil K is well documented in the literature. Hi et al. (2017) observed decreases in available soil K by grazing in some Mongolian grasslands and attributed the decreases to increased canopy biomass consumption by livestock.

Soil Organic Carbon (SOC)

SOC values obtained are 6.66g/kg, 6.24g/kg and 5.48g/kg in low, medium and high grazing treatments respectively. These values in terms of fertility are very low and are due to the near total removal of crop residue, low vegetation cover, rapid rate of organic matter mineralization resulting from high temperature and moisture conditions, bush burning and intensive cultivation in the floodplain (Ibrahim, 2011). Although the values are low, they significantly differ ($p<0.05$) from one another, and the higher the grazing intensity, the lower the SOC in the study area. This shows that grazing has effect on the SOC of the study area. An and Li (2015), in their study in a semi-arid environment, China, concluded that grazing exerts negative effects on SOC.

Consumption of plants according to Andrioli, Distel and Didone (2010) results in limited supply of organic matter to the soil, while repeated trampling by the grazing animals leads to soil compaction, a phenomenon that expels water and air from the pore spaces and decreases the microbial community that influences SOC dynamism (Zhao et al., 2017). He et al. (2011), while studying grazing intensity impacts on SOC in a continental steppe in China, concluded that prudent grazing promotes carbon (C) sequestration in the soil but heavy grazing results in C losses.

Soil CEC

The CEC values obtained are 10.38 cmol(+)/kg, 7.97 cmol(+)/kg and 6.03 cmol(+)/kg respectively for Low, Medium and High grazing intensities (Table1). These values based on rating are medium in concentrations and are significantly different ($p<0.05$) from one another (Table 1), indicating that grazing has effect on the soil CEC of the study area. Gebremedhin et al. (2018) observed decreases in CEC in grazed areas which were attributed to reduction in vegetation density, as CEC is positively related to the amount of soil organic matter. Although supply of animal dung in the areas of high intensity of grazing could boost CEC, over exposure of such organic materials could quicken the mineralization and mobility of nutrients. High δB due to compaction by animals could limit nutrient cycling and infiltration of surface materials which are eventually washed away (Stavi et al., 2008; Hi et al., 2017).

Soil Bulk Density (δB)

Results indicate that δB ranges between 1.38 and 1.78 g/cm^3 in the treatments. The DG and GF have 1.38 g/cm^3 and 1.48 g/cm^3 respectively, while the GOG recorded 1.78 g/cm^3(Tab le 1). Studies about the floodplain have reported between low and moderate δB values (Noma et al., 2004; Yakubu et al., 2008; Yakubu, Ojanuga and Noma, 2012). In this study, values recorded for

DG and GF are moderate while that recorded in GOG is high. These values are significantly different ($p<0.05$), indicating that grazing impacts on soil δB in the study area. Tate et al. (2004) studied the effect of canopy and grazing on soil δB in San Joaquin Experimental Range and discovered that cattle concentration sites had bulk densities greater than areas not grazed. Similarly, Abdalla et al. (2018), in their review on the impacts of grazing intensity on soil quality indicators in extensively managed grasslands, concluded that increased grazing resulted in increase in soil δB.

High δB has implication for seed germination, root penetration, infiltration and percolation. It also inhibits soil microbial activities and nutrient cycling, while soil tillage is made very difficult.

CONCLUSION

The results obtained from this study have shown that most of the soil properties investigated across the grazing treatments reduced in quantities with increasing grazing intensity; this is with the exception of δB and pH. The δB increased with increasing grazing intensity, while pH did not maintain a clear pattern. Based on the p-values of the ANOVA, this study concludes that grazing has reduced the quality of soil in the Rima River Floodplain. For sustainable soil resource management, government should create and demarcate some lush areas within the floodplain for animal grazing. Farmers can trade-off crop residues of their farmlands for cattle dung at no monetary cost on either side.

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