# The influence of soil properties on grass and Kob abundance in Kainji Lake National Park, Nigeria

## La influencia de las propiedades del suelo en la abundancia del césped y de Kob en el Parque Nacional del Lago Kainji, Nigeria

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## ABSTRACT

The dependence of livestock on grasses as food for sustainability has been established. However, there is limited information on the variation in soil properties on grass and animal abundance at the Kainji Lake National Park (KLNP). Therefore, the impact of soil properties on grassland and Kob were assessed at the Kainji Lake National Park, Nigeria, using an established transect [Gilbert Child (GC), Shehu Shagari (SS), Mamudu Lapai (ML), Hussain Mashi (HM) and Mara Staude (MS)]. The results indicated that variations in soil physical properties were not significantly different. However, Mamodu Lapai (ML) soil had 16.06% higher clay content compared to Hussain Mashi (HM) soils and Mara Staude (MS), and 9.61% compared to Gilbert Child (GC) and Shehu Shagari (SS) soils. Gilbert Child soil had significantly higher soil pH than ML and MS soils. Total organic carbon and total N were lowest in GC, but higher in Na contents. Grass coverage was significantly higher in GC than in MS, while SS, ML, HM, and MS had 9.67, 25.92, 12.96, and 41.97% lower grass coverage, respectively. The cluster size of Kob and the number of Kob sited were significantly higher in GC than in MS, ML, and HM. Grass abundance and Kob activity were higher under sandy soil with high soil pH and Na content but low in TOC and TN. Maintaining grass cover and animal stock at the KLNP requires a proper grazing management strategy that ensures continual maintenance of soil quality for sustainability.

## RESUMEN

Se ha establecido la dependencia del ganado de los pastos como alimento para la sostenibilidad. Sin embargo, existe información limitada sobre la variación en las propiedades del suelo, el pasto y la abundancia de animales en el Parque Nacional del Lago Kainji (KLNP). Por lo tanto, se evaluó el impacto de las propiedades del suelo en los pastizales y Kob en el Parque Nacional del Lago Kainji, Nigeria, utilizando un transecto establecido [Gilbert Child (GC), Shehu Shagari (SS), Mamudu Lapai (ML), Hussain Mashi (HM) y Mara Staude (MS)]. Los resultados indicaron que las variaciones en las propiedades físicas del suelo no fueron significativamente diferentes. Sin embargo, el suelo Mamodu Lapai (ML) obtuvo un 16,06% más de contenido de arcilla en comparación con los suelos Hussain Mashi (HM) y Mara Staude (MS), y un 9,61% en comparación con los suelos Gilbert Child (GC) y Shehu Shagari (SS). El suelo de Gilbert Child tuvo un pH significativamente más alto que los suelos ML y MS. El carbono orgánico total y el N total fueron más bajos en GC, pero mayores en los contenidos de Na. La cobertura de pasto fue significativamente mayor en GC que en MS, mientras que SS, ML, HM y MS tuvieron 9,67, 25,92, 12,96 y 41,97% menos de cobertura de pasto, respectivamente. El tamaño del grupo de Kob y el número de Kob ubicados fueron significativamente mayores en GC que en MS, ML y HM. La abundancia de pasto y la actividad de Kob fueron mayores en suelos arenosos con alto pH y contenido de Na, pero bajos en TOC y TN. Mantener la cobertura de pasto y el ganado animal en el KLNP requiere una estrategia adecuada de manejo del pastoreo que garantice el mantenimiento continuo de la calidad del suelo para la sostenibilidad.

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Grasses form the source of fodder for domesticated and undomesticated animals. Generally, livestock dependence on grasses as feed forms faces deficits of 11.2% green fodder and 23.4% dry crop residues (Roy et al. 2019). The three sources of fodder supply for livestock feeds are crop residues, cultivated fodder, and fodder from common property resources like forests, permanent pastures, and grazing lands (Roy et al. 2019). In Nigeria, grasslands form 37% (about 341,800.82 km$^2$) of the total land area (Jimoh et al. 2020). The distribution of the grasses varied along different agroecological zones in the country. These variations are based on environmental factors, including the soil fertility status. The fertility of the soil is determined by many soil properties (including pedogenetic factors) their use, and management, which are interrelated (Ramírez-Iglesias et al. 2022). Hence, soil fertility describes the present state of the soil, which means that soil fertility is a combination of soil quality (mineral composition, soil texture, soil structure, soil organic matter (SOM) content, and phosphorus concentration) (Stewart et al. 2019). Also, the soil mineral composition affects the mineral levels found in pasture, and when not in the right proportion, causes an imbalance that will compromise animal productivity (Ramírez-Iglesias et al. 2022). Consequently, these factors and human activities (including fertilization) affect the abundance and quality of grasses (Ramírez-Iglesias et al. 2022). The availability of grasses in any location, without supplementation from other sources dictates or limits the sustainability of the available resources for which livestock are dependent (Lamidi and Ologbose 2014). Eventually, this may result in overgrazing when in short supply. Studies have shown that with adequate rainfall, grass production may substantially reduce when a considerable part of the leaf surface is frequently removed by close grazing without adequate time to regrow before it is harvested again (Kirkman et al. 2023). The extent of grass availability as fodder for livestock was reported to affect the abundance of livestock that depends on grasses (Kirkman et al. 2023). Hence, location and soil fertility are essential in the sustainability of wildlife that depends on grass for sustenance. This is particularly true for antelope (*Kobus kob*) commonly found in parks across the West, Central, and Eastern parts of Africa.

The Kob are herbivorous. They eat grass and reeds and are hunted for sport and food. However, a survey has shown that they are the third most preferred species of bush meat in Central Africa (Folorunso et al. 2019). The abundance of livestock (including Kob) and the maintenance of their population are generally affected by food availability. However, there is a need to evaluate the soil properties that favor the growth and quality of grasses, thereby increasing or decreasing the abundance of Kob. Previous studies on the Kob population and density at the Kainji Lake National Park (KLNP) have not considered soil properties as an essential contributor to the dynamic of Kobs (Olajesu et al. 2019). Hence, the knowledge of the relationship between soil properties, grassland, and grazing activities at the KLNP is lacking. This understanding will enunciate knowledge-based decisions on relevant grassland management strategies required in the different locations at the KLNP. Consequently, the risks that lead to degradation conditions of the park ecosystem are minimized, thus sustaining, or improving the animal population, thereby maintaining the park functions. Therefore, the aim of this study was to evaluate soil properties as they affect the availability of grass and the abundance of Kob in KLNP.

## MATERIALS AND METHODS
### Description of the study area
The study site was at the Kainji Lake National Park, predominantly explored for park activities. The park is broadly classified into 10 transects based on their vegetation (Ikusemoran and Olokor 2014). The coordinates of the location span between 09°40'N - 10°30'N and 03°30'E - 5°50'E with approximately 5,340.82 sq. km land area. Five of the existing jeep tracks/roads transects and trails transects based on the KLNP master plan (that is, vegetation types and water availability) were randomly selected: Gilbert Child (GC), Shehu Shagari (SS), Mamudu Lapai (ML), Hussain Mashi (HM) and Mara Tsaude (MT) for this study. The transects of 5 km in length were established per site and censured for Kob species, morning (07.00 - 10.00 h) and evening (15.00 - 18.00 h).

### Soil sampling
Soil samples were collected at 0-30 cm depth from each transect. Using a grid-line survey technique with 20 m × 20 m, 35 samples were collected for the laboratory analysis of soil physical and chemical parameters. For the terraced landscapes (foot slope, back slope, and shoulder slopes), samples were taken in the middle of the terraces, while for the non-terraced crest and toe slope landscapes, samples

were collected at the maximum and minimum altitudes, respectively, for each transect.

## Soil analysis

The soil samples were air dried, ground using a pestle and mortar, and sieved to pass through a 2 mm sieve. The soil chemical properties were determined at the Service Laboratory, Department of Soil Resources Management, University of Ibadan. Soil pH was determined following the FAO (2020) procedure. The organic carbon content was analyzed using the Walkley-Black method described by Poudel (2020). Soil organic matter was calculated by multiplying soil organic carbon by the van Bemmelen conversion factor of 1.724 (Heaton et al. 2016). The total nitrogen content was determined using the Kjeldahl method (Hicks et al. 2022). The available phosphorus was determined following the Olsen procedure (FAO 2021). The cation exchange capacity (CEC) and exchangeable bases were determined after extraction of the samples with 1 N ammonium acetate at pH=7 and the $Ca^{2+}$ and $Mg^{2+}$ were measured by atomic absorption. A flame spectrometer was used for Na and K from the aliquot following the procedures described by IITA (1982). The percent base saturation was calculated by dividing the sum of base cations by the cation exchange capacity and multiplying by 100 (Culman et al. 2019). The particle size distribution of the soil was determined by the Hydrometer method (Beretta et al. 2014).

## Estimation of grass cover

The spatial distribution of grass cover (in %) during the study period was determined using a standard procedure through remote sensing by using aerial photographs and satellite images for each of the transects (Varga et al. 2014).

## Cluster and number of Kob species

The cluster and number of Kob species were determined three times a week during the dry and rainy seasons by direct observation from a high hide (observatory tower), anthill, and tree formation. The observation of the Kob species was achieved using the King Census method of enumeration for the count with the aid of Zeiss Dialyt 10 by 40 binoculars, camera, and Global Positioning System (GPS) as described by Olajesu et al. (2019). The dry season observation spanned between the months of December - March, and the rain between June - September. The other months were the transition periods between seasons.

## Statistical data analysis

Analysis of variance (ANOVA) was carried out to determine significant differences among the treatment means using SAS 9.0 software. Significant means were separated using Duncan's Multiple Range Test (DMRT) at $P<0.05$. Correlations coefficients were carried out for the relationship among the various parameters observed.

## RESULTS AND DISCUSSION
### Soil properties

The variations in soil physical and chemical properties of the locations under investigation are presented in Table 1. No significant difference was observed in the clay content among the soils from the different locations. However, soil from Mamodu Lapai (ML) had 16.06% higher clay content compared to Hussain Mashi (HM) and Mara Tsaude (MT), and 9.61% more clay content than Gilbert Child (GC) and Shehu Shagari (SS). The Silt content in the soils varied from 100.6 g kg$^{-1}$ in SS and MT to 154.0 in soil from HM, with no significance observed among the locations. The sand content was highest (805.3 g kg$^{-1}$) in soil from SS, and lowest (638.6 g kg$^{-1}$) in MT, with no significant difference observed among locations. Soil texture influences the rate at which water is available to the plant (Huntley 2023). This, according to Huntley (2023), determines the pore space in the soil and consequently the movement of water and air through its porosity and permeability. The soil textural classification did not differ among the locations, except for SS with the highest in sand content. The soils from the regions signified similarity in textural classes. The similarities in the soil's textural classifications should not impose any appreciable dissimilarities on grass coverage since they belong to the same classification. However, the distinction in the proportions of sand, silt, and clay contents of the soil may create a slight variation in grass performance, which may likely affect the abundance of animals in the different locations. According to Weil and Brady (2017), soil with relatively higher clay content (such as observed in ML soil) is likely to have better water and nutrient holding capacity and resistance to pH change, but poorer in aeration. The soil is likely to be compacted, which is not adequately suitable for grass development. However, SS soil that was relatively higher in sand content is expected to show relatively opposite qualities to ML. Furthermore, soil with a relatively high percentage of silt and clay particles has a greater erodibility than sandy soil under the same conditions thus leading to poorer grass cover (Johannes et al. 2017).

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**Table 1.** Soil physical and chemical properties across the sites in Kainji Lake National Park.

| Parameters | Gilbert Child | Shehu Shagari | Mamudu Lapai | Hussain Mashi | Mara Tsaude | P value (<0.05) |
|---|---|---|---|---|---|---|
| Clay (g kg⁻¹) | 94.0±11.5 | 94.0±0.0 | 104.0±10.0 | 87.3±6.6 | 87.3±6.6 | 0.594ns |
| Silt (g kg⁻¹) | 120.5±17.6 | 100.6±13.3 | 134.0±25.8 | 154.0±11.5 | 100.6±13.3 | 0.306ns |
| Sand (g kg⁻¹) | 792.0±20.0 | 805.3±13.3 | 762.0±34.1 | 778.6±17.6 | 638.6±17.3 | 0.582ns |
| Textural classification | Sandy loam | Loamy Sand | Sandy Loam | Sandy Loam | Sandy Loam | - |
| pH | 6.9±0.1$^c$ | 6.4±0.0$^{ab}$ | 6.3±0.0$^a$ | 6.7±0.1$^{bc}$ | 6.3±0.1$^a$ | 0.006* |
| Total organic carbon (%) | 10.2±2.5 | 18.0±5.6 | 12.7±3.0 | 21.8±1.4 | 16.5±2.6 | 0.208ns |
| Total N (%) | 0.9±0.2 | 1.6±0.5 | 1.1±0.3 | 2.0±0.1 | 1.5±0.2 | 0.209ns |
| Available P (mg kg⁻¹) | 19.7±1.5 | 19.7±1.1 | 18.6±0.7 | 21.7±0.8 | 21.8±1.0 | 0.199ns |
| Exchangeable acidity | 0.1±0.0 | 0.2±0.0 | 0.1±0.0 | 0.22±0.0 | 0.2±0.0 | 0.231ns |
| Ca (cmol kg⁻¹) | 2.2±0.5 | 2.4±0.4 | 1.6±0.4 | 3.4±0.3 | 3.3±0.6 | 0.111ns |
| K (cmol kg⁻¹) | 0.2±0.0$^a$ | 0.1±0.0$^b$ | 0.1±0.0$^b$ | 0.1±0.0$^b$ | 0.2±0.0$^a$ | 0.007* |
| Mg (cmol kg⁻¹) | 0.4±0.0 | 0.6±0.0 | 0.4±0.0 | 0.5±0.0 | 0.5±0.0 | 0.463ns |
| Na (cmol kg⁻¹) | 0.8±0.0 | 0.8±0.0 | 0.7±0.0 | 0.7±0.0 | 0.7±0.0 | 0.217ns |
| Base saturation | 95.9±0.3 | 94.2±1.4 | 94.2±1.6 | 95.8±1.3 | 94.5±1.2 | 0.811ns |
| CEC | 4.0±0.6 | 4.2±0.4 | 3.3±0.2 | 5.0±0.2 | 5.1±0.6 | 0.068ns |

Means in a row followed by the same letters are not significantly different ($P<0.05$) according to Duncan's Multiple Range Test; ns = Not significant, * = Significant at $P<0.05$.

The soil's chemical properties varied among the locations (Table 1). The soil pH differed significantly among the study sites under investigation. It differs from 6.3 in ML and MT to 6.9 in GC. Soils from ML and MT had significantly lower soil pH compared to GC and HM. Also, SS soil had significantly higher soil pH compared to GC. Although, these pH values were within the range considered adequate for good grass growth, and nutrient availability (Yue et al. 2017). In their report, soil pH affects the availability and root uptake of nutrients to the crop. However, the ability of grass to thrive under different soil pH differs within crop variety (Yue et al. 2017). The total organic carbon (TOC) did not differ significantly. However, the highest TOC was observed in soils from HM with 53.21, 17.43, 41.74, and 24.31% more compared to GC, SS, ML, and MT, respectively. The TOC serves as a major component of understanding land degradation resulting from diminished soil organic carbon (SOC) stock, hence, loss of soil condition and function (Tessema et al. 2021). This implies that HM had the highest carbon stock followed by GC, while the least was observed in MT. An increase in TOC also implied higher microbial activities and improved soil structure, consequently enhancing soil health (Silva et al. 2014). However, the depletion of TOC in grassland

has also been reported to be associated with intensive grazing activity (Ajorlo et al. 2011). Total N in the soils from the locations was not significantly different and had a similar trend as observed for the TOC. The low total N observed in GC could have been a result of overgrazing as reported by Ajorlo et al. (2011) that overgrazing results in the degradation of total soil N. Also, the soil available P values were similar in the different locations with no significant difference observed. However, HM and MT had higher available P compared to the other locations with the lowest observed in ML soil. The exchangeable acidity ranged from 0.1 (in GC and ML) to 0.22 (in HM soil), with no significant difference among the values. The Ca content was higher in the HM and MT soils and lowest in the ML soil. However, the values were not significantly different. Potassium content varied significantly among the soils from different locations. Soils from GC and MT had significantly higher K compared to the soils from other locations. Soil from SS contained the highest Mg content, while the lowest was observed in soils from GC and ML but were not significantly different. The nutrient compositions in soils from the various locations were similar in trend to the TOC. A similar finding was reported by Gerke (2022), that soil organic matter increases and improves

soil nutrients. This was attributed to the significant role of organic matter in affecting nutrient availability. The soils from the locations did not differ significantly in Na content; however, GC and SS had higher Na than the other locations. High Na in soil was reported to result in a rapid loss of the native SOC because of increased solubility, decomposability, and accessibility, hence, increasing its accessibility and degradability for the microbial population (Singh 2016). However, grasses vary in adaptation to saline conditions (Yue et al. 2017). The high Na content in GC soil can also be responsible for the low TOC, while the Na in SS soil could indicate a possible susceptibility to rapid depletion of the soil TOC. Similarly, the base saturation ranges from 95.8 in HS to 94.2 in SS and ML but was not significantly different. The CEC of the soils did not vary significantly among the locations, but MT had 21.56, 17.64, 35.29, and 1.06% higher CEC than GC, SS, ML, and HM, respectively.

**Grass cover and Kob abundance**
Grasslands serve as energy capture, soil conservation, hiding cover, bedding cover, nesting cover, and improve habitat quality (Vandever and Allen 2015). They also provide the feed base for grazing and thus numerous high-quality foods. Percent grass coverage across the locations indicated that GC had significantly higher grass coverage compared to MT (Table 2). However, compared to GC, SS, ML, HM, and MT had 9.67, 25.92, 12.96, and 41.97% lower grass coverage, respectively. This trend was similar to what was observed for Na, with GC having higher Na and relatively lower TOC. Hence, the grasses in these locations were enhanced by alkaline conditions (Yue et al. 2017). Furthermore, the higher grass coverage observed could have resulted in overgrazing (by encouraging animal influx) which led to serious grassland degradation (Mligo 2015). They reported that overgrazing results in the depletion of TOC. This explained the differences found in TOC and Na in GC. Consequently, the possibility of a higher level of soil degradation is imperative as reflected in Table 1, whereby the location had lower nutrient status. Soil quality as an indicator of improved crop performance depends on the value of other soil properties considered as the most suitable conditions for a particular crop (Johannes et al. 2017). Also, the cluster size of Kob was significantly higher at GC compared to the cluster size of Kob observed at the other locations.

**Table 2.** Influence of location differences on grass cover, cluster size of Kob, and number of Kob sited in Kainji Lake National Park.

| Parameters | Grass coverage (%) | Cluster size of Kob | No. of Kob sited |
|---|---|---|---|
| Gilbert Child | 51.70[a] | 9.19[a] | 61.00[b] |
| Shehu Shagari | 46.70[ab] | 5.76[b] | 76.00[a] |
| Mamudu Lapai | 38.30[bc] | 3.08[b] | 15.00[c] |
| Hussain Mashi | 45.00[ab] | 4.54[b] | 28.00[c] |
| Mara Tsaude | 30.00[c] | 3.59[b] | 21.00[c] |
| SE | 3.11 | 0.85 | 4.12 |

Means in a column followed by the same letters are not significantly different ($P<0.05$) according to Duncan's Multiple Range Test.

Grassland coverage indicates the carrying capacity of the location in supporting a larger number of animals. The result indicated that the GC with significantly higher grass coverage than the other locations, except HM also had a significantly higher cluster size of Kob. The finding was supported by Qi et al. (2017) report, which reported that sustainable livestock production must be accompanied by sufficient grassland size. The high cluster size in GC consolidated that there were higher activities of Kob in this location than in the others. This finding reaffirmed Olajesu et al. (2019) report that GC had a higher cluster size of Kob than the other locations under study. The basis for this assertion is that an increase in cluster size is likely to encourage high reproductive activity, concomitantly resulting in to increase in the Kob population (FAO 2018), due to the realization of an adequate food supply. However, SS had a significantly higher number of Kob sited compared to the sited Kob at GC, which also had significantly higher than the sited Kob at the other locations. This finding was substantiated by the high salt content observed in GC soil. According to Taboada et al. (2011), the level of salt accumulation at the surface of

Rev. Fac. Nac. Agron. Medellín 77(1): 10553-10561. 2024

10557

grazing land is an indication of the extent of animal activity. In their report, salt does not accumulate at the surface of the soil with limited grazing. Surface soil salt accumulation was attributed to the fact that evaporative losses were reduced with a thick layer of litter, thus decreasing the upward flux of water and salts. Hence, only minor salinity fluctuations were detected in the surface soil of pasture with limited grazing. Nevertheless, the fact that higher TOC was observed in SS soil despite similar Na content, indicated limited grazing, which could be a result of better grass quality or more grass coverage at GC.

**Correlation coefficient soil physical properties, grass cover, and Kob abundance**
The Pearson correlation coefficient among the observed

parameters indicated a non-significant correlation between clay content in the soil with silt, and sand but had a negative correlation coefficient with a cluster size of Kob and number of Kob sited (Table 3). Sand content in the sampled soil correlated significantly with the percentage of grass coverage. This finding supported Weil and Brady (2017) and Johannes et al. (2017) report that grasses are favored in well-drained soils with little silt and clay content. A high correlation coefficient also exists between grass coverage, cluster size of Kob, and number of Kob sited.

The soil pH had a significant correlation with percentage (%) base saturation (Table 4). A similar result was reported by Kabala and Łabaz (2018) that %BS increases with increasing soil pH. Also, a very high correlation coefficient

**Table 3.** Pearson correlation coefficient between the soil physical properties and grass cover, cluster, and number of Kob.

|  | Clay | Silt | Sand | Grass coverage | Cluster size of Kob |
|---|---|---|---|---|---|
| Silt | 0.08 | - | - | - | - |
| Sand | 0.38 | 0.36 | - | - | - |
| Grass coverage | 0.11 | 0.25 | 0.90* | - | - |
| Cluster size of Kob | -0.09 | -0.14 | 0.51 | 0.81 | - |
| No. of Kob sited | -0.06 | -0.44 | 0.60 | 0.73 | 0.75 |

* = Correlation is significant at $P<0.05$ level.

existed between soil pH with grass cover score and cluster size of Kob. The relationship between TOC and total N was highly significant. Similarly, total soil OC had a high correlation coefficient with Ca, Mg, CEC, and available P. Total N correlated significantly with available P, Ca, Mg, and CEC, and had significant correlation exchange acidity. A highly significant correlation existed between available P with Ca and CEC observed. Also, Ca had a very high significant correlation with CEC. The soil Na had a highly significant correlation with the number of Kob sited, while the correlation with a cluster size of Kob and grass cover was high, but not significant. Corwin and Lesch (2005) reported that water uptake by the plants under saline conditions was limited, thus increasing the soil's osmotic potential, and causing nutritional imbalances, consequently reducing plants' growth and development. However, the high correlation observed between Na and grass cover, cluster size of Kob and number of Kob sited revealed that the grasses preferred saline conditions and could lead to the deterioration of the location vegetation. Similarly, sodium

was reported to play an essential nutrient in animal feed (Johansson 2008). Salt helps in maintaining the right level of mineral balance of the animals and keeps the livestock healthy. There are; however, limits to its requirement to prevent food poisoning (EFSA 2019). Furthermore, studies have indicated that high salinity beyond the threshold level hinders root growth and causes drought symptoms (Vandever and Allen 2015). These salts could compete with the plant roots for available water. Consequently, under drought conditions, soil salts pull water out of plant roots through osmotic pressure, causing them to dehydrate or desiccate. High salt concentrations in the soil could burn young tender roots and prevent normal development. Similarly, intensive grazing causes an increase in topsoil temperatures, thus leading to higher soil water evaporation rates (Taboada et al. 2011). The various correlation was in support of Ajorlo et al. (2011), indicating the effects of varying level of overgrazing activities of Kob across the location on the soil properties of the different locations under investigation.

**Table 4.** Pearson correlation coefficient between the soil chemical properties, grass cover, cluster, and number of Kob.

| ` | pH | Total OC | Total N | Ava. P | Exch. acidity | Ca | K | Mg | Na | Base saturation (%) | CEC |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Total OC | -0.16 | - | - | - | - | - | - | - | - | - | - |
| Total N | -0.13 | 0.99** | - | - | - | - | - | - | - | - | - |
| Ava. P | 0.09 | 0.66 | 0.69 | - | - | - | - | - | - | - | - |
| Exch. acidity | -0.20 | 0.93* | 0.94* | 0.78 | - | - | - | - | - | - | - |
| Ca | 0.10 | 0.74 | 0.77 | 0.99** | 0.85 | - | - | - | - | - | - |
| K | 0.27 | -0.50 | -0.46 | 0.29 | -0.22 | 0.20 | - | - | - | - | - |
| Mg | -0.31 | 0.72 | 0.70 | 0.36 | 0.83 | 0.46 | -0.33 | - | - | - | - |
| Na | 0.44 | -0.35 | -0.36 | -0.39 | -0.22 | -0.34 | 0.17 | 0.22 | - | - | - |
| Base saturation (%) | 0.94* | 0.01 | 0.05 | 0.35 | -0.04 | 0.34 | 0.30 | -0.34 | 0.14 | - | - |
| CEC | 0.08 | 0.69 | 0.72 | 0.99** | 0.84 | 0.99** | 0.28 | 0.49 | -0.27 | 0.30 | - |
| Grass coverage | 0.79 | -0.15 | -0.15 | -0.34 | -0.24 | -0.28 | -0.16 | -0.03 | 0.75 | 0.57 | -0.29 |
| Cluster size of Kob | 0.82 | -0.44 | -0.43 | -0.18 | -0.34 | -0.17 | 0.43 | -0.16 | 0.84 | 0.61 | -0.12 |
| No. of Kob sited | 0.39 | -0.10 | -0.11 | -0.25 | 0.03 | -0.17 | 0.03 | 0.45 | 0.97** | 0.11 | -0.11 |

OC = Organic carbon; Ava. P = Available P; Exch. acidity = exchange acidity; CEC = Cation exchange capacity; *, ** = Correlation is significant at $P<0.05$, t, $P<0.01$ levels, respectively (2-tailed).

## CONCLUSIONS

The impact of different soil properties on grass coverage and animal abundance at the KLNP transect under investigation is confirmed by this study. Sand, silt, and clay contents in the locations were similar, but GC and SS soils were sandier than the other locations. Soil from GC with lower TOC and TN, but higher soil pH and Na contents had higher grass coverage and the cluster of Kob sizes. The order of grass coverage and cluster sizes of Kob were GC>SS>HM>ML>MT and GC>SS>HM>MT>ML, respectively. Sand and grass coverage were highly correlated, while soil Na content and the number of Kob sited had a high correlation. Based on the findings of this study, grass coverage, and Kob activity increased under sandy soil, high in soil pH and Na content but low in TOC and TN. However, to maintain good quality grass cover and animal stock at the KLNP, a proper grazing management strategy is critical to ensure continual maintenance of soil quality for sustainability.

## REFERENCES

Ajorlo M, Abdullah R, Mohd Hanif AH, Abd Halim R and Yusoff Mohd K (2011) Impacts of livestock grazing on selected soil chemical properties in intensively managed pastures of Peninsular Malaysia. Pertanika Journal of Tropical Agricultural Science 34(1): 109-121.

Beretta AN, Silbermann AV, Paladino L, Torres D, Bassahun et al (2014) Soil texture analyses using a hydrometer: modifications of the Bouyoucos method. Ciencia e Investigación Agraria 41(2): 263-271. http://doi.org/10.4067/S0718-16202014000200013

Corwin D and Lesch SM (2005) Apparent soil electrical conductivity measurements in agriculture. Computers and Electronics in Agriculture 46: 11-43.

Culman S, Mann M and Brown C (2019) Calculating cation exchange capacity, base saturation, and calcium saturation (ANR-81). Ohio State University Extension. https://ohioline.osu.edu/factsheet/anr-81; accessed: November 2023.

EFSA Panel on Additives and Products or Substances used in Animal Feed (FEEDAP), Bampidis V, Azimonti G, Bastos ML, Christensen H, Dusemund B, Kouba et al (2019) Scientific opinion on safety and efficacy of sodium selenate as feed additive for ruminants. EFSA Journal 17(7): 5788. 21 p. https://doi.org/10.2903/j.efsa.2019.5788

FAO (2018) Guidelines on methods for estimating livestock production and productivity. FAO Publication: Rome. 173 p. https://www.fao.org/3/ca6400en/ca6400en.pdf

Rev. Fac. Nac. Agron. Medellín 77(1): 10553-10561. 2024

10559

FAO (2020) Soil testing methods - Doctors Global Programme -  A farmer-to-farmer training programme. Rome.  105 p.  https://doi.org/10.4060/ca2796en

FAO (2021) Standard operating procedure for soil available phosphorus - Olsen method. Food and Agriculture Organization of the United Nations. Rome. https://www.fao.org/3/cb3644en/cb3644en.pdf; accessed: November 2023.

Folorunso AA, Lewiska LF, Akeem LG and Oladipo OS (2019) Population density, diversity and abundance of antelope species in Kainji Lake National Park, Nigeria. Open Journal of Ecology 9: 107-116.  https://doi.org/10.4236/oje.2019.94009

Gerke J (2022) The central role of soil organic matter in soil fertility and carbon storage. Soil Systems 6: 33. https://doi.org/10.3390/soilsystems6020033

Heaton LM, Fullen A and Bhattacharyyai R (2016) Critical analysis of the van Bemmelen conversion factor used to convert soil organic matter data to soil organic carbon data: comparative analyses in a UK loamy sand soil. Espaço Aberto 6(1): 35-44. https://doi.org/10.36403/cyberspace.2016.5244

Hicks TD, Kuns CM, Raman C, Bates ZT and Nagarajan S (2022) Simplified method for the determination of total kjeldahl nitrogen in wastewater. Environments 9: 55. https://doi.org/10.3390/environments9050055

Huntley BJ (2023) Soil, water and nutrients. In: Ecology of Angola. Springer, Cham. pp.127-147. https://doi.org/10.1007/978-3-031-18923-4_6.

IITA (1982) Automated and Semi-Automated Methods of Soil and Plant Analysis, Manual Series No.7. IITA, Ibadan. 33 p.

Ikusemoran M and Olokor JO (2014) Monitoring the land-use and vegetation cover changes in the Kainji Lake Basin, Nigeria (1975-2006). African Journal of Environmental Science and Technology 8(2): 129-142.

Jimoh SO, Muraina TO, Bello SK and NourEldeen N (2020) Emerging issues in grassland ecology research: Perspectives for advancing grassland studies in Nigeria. Acta Oecologica 106:103548. https://doi.org/10.1016/j.actao.2020.103548

Johannes A, Matter A, Schulin R, Weisskopf P, Baveye P and Boivin P (2017) Optimal organic carbon values for soil structure quality of arable soils. Does clay content matter? Geoderma, 302: 14-21 p. https://doi.org/10.1016/j.geoderma.2017.04.021

Johansson K (2008) Salt to ruminants and horses. Department of Animal Nutrition and Management, Swedish University of Agricultural Sciences, Uppsala. 31 p. https://core.ac.uk/reader/11987906; accessed: February 2023.

Kabala C and Łabaz B (2018) Relationships between soil pH and base saturation - Conclusions for Polish and international soil classifications. Soil Science Annual 69: 206-214. http://doi.org/10.2478/ssa-2018-0021

Kirkman KP, Fynn RWS, McGranahan D, Dugmore T and O'Reagain PJ (2023) Future-proofing extensive livestock production in subtropical grasslands and savannas. Animal Frontiers: The Review Magazine of Animal Agriculture 13(5): 23-32. https://doi.org/10.1093/af/vfad045

Lamidi AA and Ologbose FI (2014) Dry season feeds and feeding: a threat to sustainable ruminant animal production in Nigeria. Journal of Agriculture and Social Research 14(1): 17-30.

Mligo C (2015) The impact of livestock grazing on soil characteristics in Mount Kilimanjaro, Tanzania. Journal of Geoscience and Environment Protection 3: 24-37. http://doi.org/10.4236/gep.2015.39004

Olajesu SO, Akinyemi AF, Lateef FL and Lameed GA (2019) Population density, diversity and abundance of antelope species in Kainji Lake National Park, Nigeria. Open Journal of Ecology 9: 107-116.

Poudel S (2020) Organic matter determination (Walkley-Black method) IAAS, Paklihawa Campus. https://doi.org/10.13140/RG.2.2.22043.00807

Qi J, Xin X, John R, Groisman P and Chen J (2017) Understanding livestock production and sustainability of grassland ecosystems in the Asian Dryland Belt. Ecological Processes 6(1): 22.  https://doi.org/10.1186/s13717-017-0087-3

Ramírez-Iglesias EI, Lozano-Pérez Z, Hernández-Hernández RM and Ramírez-Iglesias JR (2022) Forage quality in a neotropical savanna based on different types of fertilization. Revista Facultad Nacional de Agronomía Medellín 75(2): 9929-9940. https://doi.org/10.15446/rfnam.v75n2.96791

Roy AK, Agrawal RK, Bhardwaj NR, Mishra AK and Mahanta SK (2019) Revisiting national forage demand and availability scenario. In: AK Roy, RK. Agrawal N R Bhardwaj (eds.) Indian fodder scenario: Redefining state wise status. ICAR- AICRP on Forage Crops and Utilization, Jhansi, India, pp.1-21.

Silva A, Babujia L, Franchini J, Ralisch R, Hungria M and Fatima M (2014) Soil structure and its influence on microbial biomass in different soil and crop management

systems. Soil and Tillage Research 142: 42-53. https://doi.org/10.1016/j.still.2014.04.006

Singh K (2016) Microbial and enzyme activities of saline and sodic soils. Land Degradation and Development 27(3): 706-718. https://doi.org/10.1002/ldr.2385

Stewart ZP, Pierzynski GM, Middendorf BJ and Vara Prasad PV (2019) Approaches to improve soil fertility in sub-Saharan Africa. Journal of Experimental Botany 71(2): 632-641. https://doi.org/10.1093/jxb/erz446

Taboada MA, Rubio G and Chaneton EJ (2011) Chapter 20 - Grazing impacts on soil physical, chemical, and ecological properties in forage production systems. pp. 301-320. In: Hatfield JL and Sauer TJ (eds.). Soil management: Building a stable base for agriculture. American Society of Agronomy and Soil Science Society of America, Madison, USA. 409 p. http://doi.org/10.2136/2011.soilmanagement.c20

Tessema BG, Daniel H, Adimassu Z and Wilson B (2021) Chapter 2 - Soil Carbon storage potential of tropical grasses: A review. In: Ghimire BK. (ed.) Botany - Recent advances and applications. IntechOpen. http://doi.org/10.5772/intechopen.97835

Vandever MW and Allen AW (2015) Management of conservation reserve program grasslands to meet wildlife habitat objectives: U.S. Geological Survey Scientific Investigations Report 2015-5070. USA. 47 p. http://doi.org/10.3133/sir20155070

Varga K, Szabó S, Szabó G, Dévai G and Tóthmérész B (2014) Improved land cover mapping using aerial photographs and satellite images. Open Geosciences 7(1): 15-26. https://doi.org/10.1515/geo-2015-0002

Weil R and Brady N (2017) The nature and properties of soils. 15th edition. Pearson Education, Columbus, Ohio, 980 p.

Yue X, Han X, Song Q, Yang X and Zhou Q (2017) Research on screening of suitable forage grasses in coastal saline - alkaline soils. IOP Conference Series: Earth and Environmental Science 94 012014. http://doi.org/10.1088/1755-1315/94/1/012014

Rev. Fac. Nac. Agron. Medellín 77(1): 10553-10561. 2024

10561