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Comparative Study of Soil Profile in Logo and Ukum Local Government Areas of Benue State, Nigeria

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Abstract

Soil samples were collected from Mbagber and Mbazum council wards of Logo and Ukum Local Government Areas of Benue State. Physicochemical analysis was conducted to assess the soil fertility. The results indicate that the soil profile (sand, clay and silt) is 74.96 %, 13.75 % and 10.34 % for Logo and 74.13 %, 14.41 % and 9.44 % for Ukum. Bulk density, soil porosity, moisture content and organic carbon were found to be 1.54 gcm⁻³ and 1.35 gcm⁻³, 42.48 % and 49.54 %, 23.80 % and 20.73 %, 0.52 % respectively for both Logo and Ukum respectively. The results for pH, CEC, BS and total nitrogen were 6.25 and 6.29, 7.1 Cmolkg⁻¹ and

6.95 Cmolkg⁻¹, 86.08 % and 85.24 %, 6.09 Cmolkg⁻¹ and 6.03 Cmolkg⁻¹ and 0.19 % and 0.40 % for Logo and Ukum respectively. Phosphorus, potassium, and calcium values were found to be 2.71 ppm and 2.65 ppm, 2.94 Cmolkg⁻¹ and 2.94 Cmolkg⁻¹ for Logo and Ukum respectively. The study revealed that all the parameters are in agreement with set standards by United State Department of Agriculture soil standard range (USDA SSR) with low CEC value indicate that the soil requires fertilizer (organic fertilizers, slow released fertilizers, balanced fertilizers etc) application for maximum yield.

Keywords: Physical Properties, Chemical Properties, Essential Elements, Farmers, Nutrients

1. Introduction

Among the foremost challenges faces by Nigerian farmers in the production of adequate food is the extensive degradation of farmlands due to human and natural activities (Oyetola *et al.*, 2021) ^[18]. Human activities responsible for land degradation include: escalation of land tillage for the production of food to meet the growing population, upsurge in pastoralism or animal husbandry and the used of wood as fuel in place of conventional fuel due to its high cost. These human activities can expose the soil surface and make it susceptible to weathering (Macaulay, 2014) ^[14]. While the natural activities may include change in climatic condition (rain fall, temperature and) and weathering.

In addition, there has been a steady decline in soil productivity due to intensive cultivation and inadequate soil administration policies nationwide. According to Yakubu and Ishaku (2019) ^[25], sustaining soil resources implies the use of effective agricultural practices, contrarily to this will lead to deterioration in quality and quantity of soil within a very short timeframe. Agricultural practices or administrations that preserve soil fertility status should be recommended to farmers and environmentalists through government policymakers.

These practices will lead to upsurge in productivity with effective use of nutrients, pesticides, reduction in greenhouse gas emissions (Yakubu and Ishaku, 2016).

Soil rich in nutrients is considered fertile, resulting in high crop yields. However, soil fertility varies among different soil types, with each type being suitable for specific crops. Soil lacking essential nutrients must be improved by applying organic and inorganic fertilizers. Soil type determines the frequency of fertilizer application. Sandy soils need more frequent applications and lower amounts of nitrogen and other nutrients compared to clay soils. Factors like the type of crop being grown also influence how often fertilizer should be applied. For instance, root crops require less nitrogen fertilization than leafy crops. Generally, nitrogen-based fertilizers promote leafy top growth, phosphorus supports root and fruit production, and potassium enhances cold hardiness, disease resistance, drought tolerance, and overall durability. For example, the application of nitrogenous fertilizers on tomatoes may lead to the production of vines and no fruits. Similarly, its application on potatoes, will show excess vining and poor tuber formation. Slow-release fertilizer or heavy amounts of manure used on crops that form

fruits will maintain vegetative growth and fruit, or vegetable development will occur late in the season. Proper nutrient management can regulate plant growth rate and productivity. Therefore, assessment of a particular soil will not only involve measuring soil properties and using the measured values to detect changes in soil as a result of land use or management practices. According to Zubairu *et al.*, (2023) [24], climate and geological history are importance factors which affect soil properties on regional and continental scales. However, under small catchment scale, land use may be the dominant factor affecting soil properties.

Considering the rapid growth of the population of Nigeria, improving crop productivity and resource use efficiency is highly required to ensure food security and environmental quality. The best way to reach this goal is to increase yield per unit area rather than by expansion of the cultivated area (Abdulkadir *et al.*, 2022) [2]. In this respect, evaluating soil's physicochemical properties could greatly help in improving agricultural productivity. The fertility of the soil is determined by both its physical, chemical properties and nutrient contents.

Soil nutrient depletion has grave implication leading to widespread deficiency of macro and micro nutrients of such as N, P, K, Ca, Zn, B, S, increased soil pH levels as well as cation exchange capacity (CEC); a weakened foundation for high yielding sustainability farming, and escalating remedial cost on rebuilding depleted soil fertility evaluation

(analysis).

The decline in soil fertility has imposed a national problem of food insecurity (Abdulkadir, *et al.*, 2022) [2]. Some of the elements such as nitrogen (N), phosphorus (P) and potassium (K) are given more attention in Nigeria in evaluating soil fertility because of plants' urgent need for them and the common deficiency of these elements in most Nigerian soils (Ahola, *et al.*, 2021) [5]. Several researches on soil physicochemical parameters have been conducted around the world but information on the physical and chemical properties of soils of Logo and Ukum Local Government area of Benue State is limited. Nevertheless, this region is recognized for its high yield in yam production and other crops such as soybeans and groundnuts in Benue State. This research aims to assess the physicochemical properties of the soil from these areas and relate it to the increased production of yams in the state.

2. Materials And Methods

2.1 Study Areas

This research was carried out in Mbagber and Mbazum wards in Logo and Ukum Local Government Area (LGA) of Benue State respectively. Logo LGA is located at latitude 7° 54'N and longitude 9° 18'E, while, Ukum LGA is located at latitude 7° 25'N to 7° 45'N and longitude 9° 15'E to 9° 43'E. The two local government areas are agrarian and are known for their higher production of yams, groundnuts and soya beans in the state.

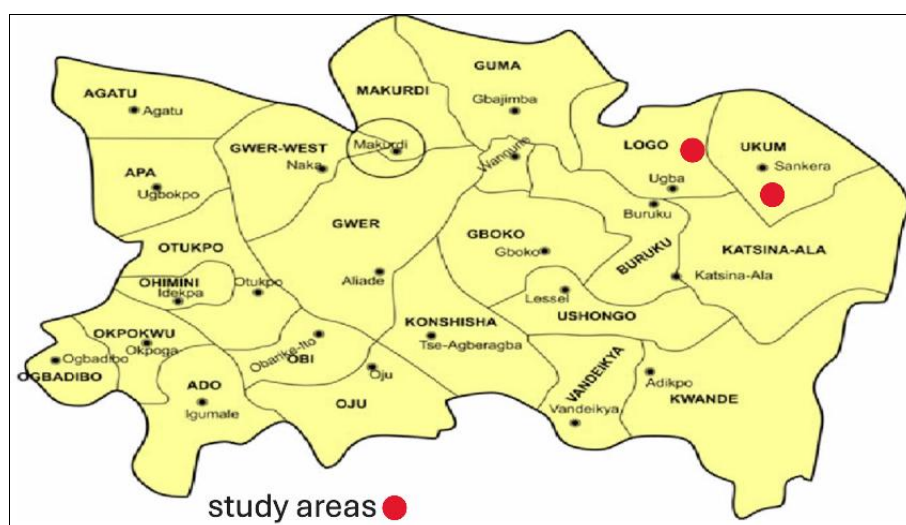


Fig 1: Map of Benue State showing study areas

2.2 Soil Sampling and Preparation.

Random sampling technique was used to collect soil samples in each location. A total of ten composite samples (five from each site) were collected at a depth of 0-30 cm using soil push probe. The samples were taken into polythene bags and labeled accordingly for analysis. The collected soil samples were air dried, gently crushed and sieved through 2 mm mesh and stored in screw capped dark bottles for laboratory analysis.

2.3 Determination of pH

The pH of the soil samples was determined with Orion Research Analog pH metre/model 30 L according to standard analytical methods. About 20 g of the soil sample was weighed into a 50 ml beaker and 20 ml of distilled water was added and allowed to stand for 30 minutes while

stirring with glass rod. The electrodes of the pH meter were inserted into the suspension and triplicates determinants were recorded.

2.4 Cation Exchange Capacity (CEC)

Exactly 5.00 g of soil was measured into 250 mL Erlenmeyer flask and 125 mL of 1M Ammonium acetate was added and shake thoroughly and allow to stand for overnight. Sample was then filtered using suction in a Buchner funnel with retentive filter paper which was moisten. The filtered soil sample was washed four times with 25 mL addition Ammonium acetate, allowing each addition to filter through but not allowing the soil to crack or dry. Only suction only was applied to ensure slow filtering. The leachate was discarded leaving exchangeable cations for determination after diluting it to 250 mL. The

soil sample was then washed with eight separate additions of 95 % ethanol to remove excess saturated solution by adding just enough ethanol to cover the soil surface, and allow each addition to filter through before adding more. Again the leachate was discarded the receiving flask cleaned. The adsorbed ammonium ion was extracted by leaching the soil with eight separate 25 mL additions of 1 M KCl, leaching slowly and completely as above. The samples were discarded and the leachate was transfer to a 250 mL volumetric flask. The volume was diluted with additional KCl. The concentration of ammonium ion- nitrogen ($\text{NH}_4 - \text{N}$) in the extracted potassium chloride by distillation was done by colorimeter. Also ammonium ion- nitrogen ($\text{NH}_4 - \text{N}$) was in the original KCl extracting solution (blank) was determine by adjusting for possible $\text{NH}_4 - \text{N}$ contamination in this reagent.

Calculations

Where:

$\text{NH}_4 - \text{N}$ is reported in mg N/L:

$\text{CEC (cmol c /kg)} = (\text{NH}_4 - \text{N}_{\text{in extract}} - \text{NH}_4 - \text{N}_{\text{in blank}}) / 14$

Where $\text{NH}_4 - \text{N}$ is reported in mg NH_4 / L :

$\text{CEC (cmol c /kg)} = (\text{NH}_4 - \text{N}_{\text{in extract}} - \text{NH}_4 - \text{N}_{\text{in blank}}) / 18$

2.5 Determination of Moisture Content

The gravitational method was used to determine the moisture content of the soil. About 5 g of the soil sample was weighed and transferred into a Petri-dish. The sample in the dish was placed in an oven at a temperature of 105 °C for 5 hours to completely dry off the wet soil. The dried soil sample was re-weighed. The difference between the initial weight (before heating) and final weight (after heating) was taking and recorded. The moisture content was calculated using the formula below:

$$\% \text{ Moisture content} = \frac{M_1 - M_2}{M_1} \times 100 \quad (1)$$

Where M_1 is initial mass of wet sample, and M_2 is final mass of oven-dried sample.

2.6 Determination of soil particle size

The soil particle size distribution was determined by the Bouyoucos hydrometer method (Bouyoucos., 1962) [9]. 100g of each soil sample was analyzed, in which 50ml of calgon was used as a dispersing agent. 200 ml of water was added, stirred and kept for 24 hours so that the dispersion in circulating the soil particle can be completed. Then it was pulled into a measuring cylinder of 1000 ml for the particles to settle for reading.

2.7 Determination of Bulk Density

Bulk density was determined using the core sample method (Blake and Hartge, 1986). About 10 g of the soil was transferred into a calibrated test tube. 5 mL of distilled water added into the test tube gradually and the soil was allowed to absorb the water molecules until it is fully saturated without the water level going above the soil level in the test tube. The soil bulk density was then calculated using the formula below.

$$\text{Bulk Density} = \frac{\text{Mass of soil}}{\text{Volume of water}} \quad (2)$$

2.7.1 Determination of soil porosity

The soil porosity was obtained from bulk density value and assumed particle density of 2.65 Mg m^{-3} using the expression:

$$\text{Soil Porosity} = 1 - \frac{\text{Bulk density}}{\text{Particle density}} \quad (3)$$

2.7.2 Determination of Organic Carbon in Soil

The walkley and black methods as described by Nelson and Sommers (2008) were used in the analysis of soil organic carbon.

About 10 ml of sulphuric acid (H_2SO_4) and 10 ml of 1N potassium dichromate ($\text{K}_2\text{Cr}_2\text{O}_7$) solutions were transferred in a conical flask containing 1 g of soil and was allowed to stand for 30 minutes after shaking. 50 ml of distilled water, 5 ml of orthophosphoric acid and 1 - 3 drops of barium diphenyl indicator were added. There was a change in colour from light brown to maroon at end point when titrated against iron sulphate (FeSO_4) solution.

2.7.3 Determination of Organic Matter

The organic matter in soil was obtained from the organic carbon using the formula:

$$\% \text{ Organic Matter} = \% \text{ Organic Carbon} \times 1.729 \quad (4)$$

2.7.4 Determination of Total Nitrogen

Total nitrogen was analyzed using the Kjeldahl distillation method as described by Black (1965). About 2 g of soil samples were transferred into the digestion flask. 1 tablet of selenium catalyst (Kjeldhal Catalyst) was added to 10 ml of concentrated sulphuric acid (H_2SO_4). The flask was placed in the digestion block and was heating for 1 hour and then allowed to cool. Distilled water was added to the digest to make it 30 ml. 10 ml of the digest was taken for distillation in Kjeldhal flask with 15 ml and 30 ml of sodium hydroxide (NaOH) solution and distilled water respectively. The distillate was received in a 20 ml of boric acid indicator. The distillate was then titrated with 0.01 N sulphuric acid (H_2SO_4).

2.7.5 Determination of Phosphorus in Soil

Bray-1 method was used for available phosphorus extraction (Landon, 1991) and read using a spectrophotometer at 860 nm (Murphy and Riley, 1962). About 5 ml of Bray-1 extract was transferred into a flat bottom flask containing of 2 g of soil. Exactly 2 ml of ammonium molybdate solution and 1 ml of dilute standard chloride were added to the soil solution and shake vigorously. There was a change from colorless to light blue colouration and readings were taken (Bray and Kurts, 1945) [10].

2.7.6 Determination of Exchangeable Cations and cation exchange capacity

Exchangeable Ca and Mg in the extracts were analyzed using atomic absorption spectrophotometer, while Na and K were analyzed by a flame photometer (Anderson and Ingram, 1993). Cation exchange capacity (CEC) was determined titrimetrically by distillation of ammonium that was displaced by sodium from NaCl solution (Chapman, 1965).

2.7.7 Data Analysis

Statistical analysis was performed using SPSS (Statistical Package for Social Sciences, version 20). The soil's physical and chemical properties were subjected to statistical test of

mean and standard deviation to assess significant variation in concentration level of the various samples.

3. Results and Discussion

The particle size distribution of the soil in both sampling sites indicates sandy with the highest average values of 74.96% in Logo and 74.13 % in Ukum (Table 1). Low percentage silt (9.44 % and 10.34%) and clay (73.75 % – 14.41 %) were observed for Ukum and Logo respectively. High level of clay was observed in Logo LGA with an average value of 73.75 %. This could be attributed to variations in the study area may be the difference in topography, slope gradient and parent material. Okorafor *et al.* (2021), reported that variation in soil texture may be caused by variation in parent material, topography, in situ weathering and translocation of clay. Soils of lower elevation sites are known to have had higher clay content than those of higher elevations (Nasiru, *et al.*, 2020) [15]. From the results, it can be concluded that the particle size distribution of the study areas compared favourable within the permissible ranges for a fertile soil according to Standard Rating of Nigeria Soil.

The average bulk density values were found to be 1.54 and 1.35 (Table 1) for Logo and Ukum respectively. These values are rated as moderate and are considered to favour good aeration, root penetration and free water movement in the soil. These results are in agreement with those reported by Oyetola *et al.*, (2021) [18]; Gundu, *et al.*, 2020, observed that plants perform best in bulk densities within 1.4 g/cm³ and 1.6 g/cm³ for clay and sandy soils respectively. Higher bulk density above 1.6 g/cm³ tends to inhibit root growth. This is due to soil's resistance to root penetration, poor aeration, slow movement of nutrients and water and buildup of toxic gases and root exudates as explained by Agber *et al.* (2017) [4].

The highest average value for total porosity was found to be for Ukum LGA as 49.54 % and 42.48 % was for Logo, all of which falls within the permissible limit given by Standard Rating of Nigeria Soil. Porosity is the measure of the ease with which water and air move through the soil and this depend on the soil texture, structure and organic matter content. The porosity indicates that the soil has high tendency to support a variety of crops.

The average percentage moisture content of the soil was found to be 23.80 % in Logo while 20.73 % (Table 1) was observed in Ukum. Moisture content is the soil's water holding capacity. There is no significant different in the moisture content due to the high proportion of sand particles, and low clay percentage in the soil of the sampling sites. Moisture influences the rate of nutrients uptake by plants (Ahola *et al.*, 2021) [5].

The results of the organic carbon were found to be 0.52 % and 0.60 % for Logo and Ukum respectively. Organic carbon is the carbon stored in organic matter. It is formed as a result of plant and animal decay. Soil organic carbon is the basis of soil fertility. It releases nutrient for plant growth. High soil organic carbon improves soil health and fertility (Sangita C.D., 2020) [20]. The organic carbon values for both sampling sites are within the permissible limit by Standard Rating of Nigeria Soil of 0.5-1.5.

The organic matter content of the soil was found to be higher in Ukum 1.04 % compared to 0.91 % recorded at Logo (Table 1). This significant amount of organic matter content recorded in the soils could be ascribed to the

decomposition of plant remains from dead soil macro fauna and micro-organisms in the reserves. Soil organic matter refers to plant and animal remains returned to the soil through decomposition processes. Soil organic matter has influence on soil structure, water holding capacity, nutrient contributions, biological activity, water and air infiltration rate and pesticide activity. A soil with high level organic matter is an indication of high cation exchange capacity, holds more water and increases biological activities (Abdulhamid, *et al.*, 2015) [1]. The low values of organic matter recorded in both areas are attributed to continuous farming without fallowing, although the values fall with the permissible limits.

Table 1: Physical properties of soil in Logo and Ukum LGA

Parameters	Logo LGA	Ukum LGA	SRNS
Sand (%)	74.96±1.88	74.13±2.47	-
Clay (%)	13.55±1.54	14.41±2.23	-
Silt (%)	10.34±2.11	9.44±2.63	-
Bulk density (gcm ⁻³)	1.54±0.07	1.35±0.03	0.1-1.60
Porosity (%)	42.48±2.48	49.54±1.22	40-60
Moisture (%)	23.80±0.51	20.73±3.67	15-30
Organic carbon (%)	0.52±0.04	0.60±0.04	0.5-1.5
Organic matter (%)	0.91±0.15	1.04±0.24	2.00-3.00

SRNS: Standard Rating of Nigeria Soil

Table 2: Chemical properties of soil in Logo and Ukum LGA

Parameters	Logo	Ukum	USDA SSR.
pH	6.25±0.07	6.29±0.03	5.5-8.5
CEC (Cmolkg ⁻¹)	7.10±0.46	6.95±0.65	6-40
BS (%)	86.08±0.67	85.24±1.09	20->80
TEB (Cmolkg ⁻¹)	6.09±0.48	6.03±0.73	-
EA (Cmolkg ⁻¹)	1.01±0.02	1.03±0.05	0.4-5.6

USDA SSR: United State Department of Agriculture soil standard range

The pH values of the soil were found to be slightly acidic in both sites (Logo and Ukum LGA) with values of 6.25 % and 6.29 % (Table 2) respectively. pH measures the relative conc. of hydrogen ion in the solution. pH is an important parameter as it helps in ensuring availability of plants nutrients example Fe, Mn, Zn and Cu are more available in acidic than alkaline soils. It also helps in maintaining the soil fertility and to quantify the amendments used for amelioration. pH is a good sign to maintain equilibrium between nutrients in soil. It is also an indicator of plant and other living organism, available nutrients, cation exchange capacity and organic matter content (Zubairu, *et al.*, 2023) [24]. The pH of the study areas falls within the permissible limit set by USDA.

The cation exchange capacity (CEC) values for both sites (Logo and Ukum) (Table 2) were found to be 7.10 Cmolkg⁻¹ and 6.95Cmolkg⁻¹ respectively. Cation exchange capacity values of below 12 Cmol/kg are considered minimum value of fertile soil (Maniyunda and Malgwi, 2011). This is the measure of the ability of soil to attract, retain and exchange cationic elements at a particular pH. Moderate CEC of the soil implies that with continuous cultivation (rainfed agriculture) without proper management practices, the soil may undergo rapid physical and chemical degradation. The low CEC of the soils implies that with continuous cultivation (rainfed and irrigated agriculture), the soils would undergo rapid degradation physically and chemically. The incorporation of organic matter and addition of bases

under fertilizer programme would raise CEC of these soils. Although the CEC of the study areas falls within the permissible limit set by USDA.

The base saturation (BS) of the soils of the study areas were found to be generally high in both Logo and Ukum LGA 86.08 % and 85.24 % (Table 2) respectively. Base saturation is the measure of the proportion of the total CEC occupied by basic cations. Base saturation values greater than 50 % indicate fertile soils while values less than 50 % indicate low fertility (FAO – UNESCO, 1998) ^[11]. This implies that, the soils of two farm sites are considered fertile.

The total exchangeable base (TEB) values were found to be 6.09 Cmol/kg and 6.03 Cmol/kg for Logo and Ukum LGA respectively. No significant difference was found in the values of the TEB in both study areas. TEB is the sum of all the exchangeable bases.

Similar values for exchangeable acid were recorded in both study areas as 1.01 Cmol/kg and 1.03 Cmol/kg (Table 2) for Logo and Ukum LGA respectively. The values are in compliance with the United State Department of Agriculture soil standard ranges.

Table 3: Essential elements in soil from Logo and Ukum LGA

Essential elements	Logo	Ukum	USDA SSR
TN (%)	0.19±0.02	0.40±0.03	0.04-0.08
P(ppm)	2.71±1.08	2.65±0.33	13-25
K (Cmolkg ⁻¹)	0.27±0.12	0.22±0.03	0.2-2.0
Ca (Cmolkg ⁻¹)	2.94±0.22	2.94±0.36	2-20
Mg (Cmolkg ⁻¹)	2.65±0.24	2.64±0.33	0.3-8
Na (Cmolkg ⁻¹)	0.24±0.02	0.24±0.03	0.1-2.0

USDA SSR: United State Department of Agriculture soil standard ranges

The total Nitrogen contents (%) were recorded as 0.19 % and 0.40 % (Table 3) for Logo and Ukum respectively. Nitrogen is one of the major elements required for life, it stimulate growth in plants. It helps protein synthesis and the formation of enzymes and chlorophyll molecules. Its deficiency will cause stunted growth, yellow colour appearance on older leaves in crops (Adamu *et al.*, 2016) ^[3]. This high nitrogen content in the soils could be attributed to the high organic matter content and application of nitrogen containing fertilizers. The study revealed that the total nitrogen content of the soils could be categorized high to very high according to the guidelines suggested by FAO (2006). In field crops especially cereals, nitrogen is a very important nutrient of high demand because these crops are by nature incapable of fixing the free atmospheric nitrogen (Amara and Momoh, 2014).

The average values recorded for phosphorus were 2.71 ppm for Logo and 2.65 ppm for Ukum. These low values are attributed to the slightly acidic pH (6.25 and 6.29) of the soils.

Which is not suitable for solubility and release of phosphorous in the soil. These results conform to the findings of Ajon and Anjembe (2018) ^[6], that phosphorus is a limiting nutrient in many sandy soils of the semi-arid tropics. The most limiting nutrient in tropical soils can be regarded as soil nitrogen followed by phosphorus and the soils of Nigeria are known to be deficient in available phosphorus (Abdulhamid, *et al.*, 2015) ^[1]. However, the present study has revealed that there is a need for soil scientists to review the phosphorus status of soils of Nigeria in order to ascertain whether the widely held notion of low

phosphorus in soils of Nigeria is still holding or not (Akintola *et al.*, 20220).

The potassium contents of the soil samples were found to be 0.27 Cmolkg⁻¹ and 0.22 Cmolkg⁻¹ (Table 3) for Logo and Ukum respectively. Potassium plays an important role in different physiological processes of plants. Potassium is major nutrient for the production of superior quality crop. Its main role is catalytic in nature. Its content indicates that the soil of the study areas is rich in potassium as it falls within the permissible limit prescribed by United State Department of Agriculture soil standard ranges.

The calcium contents of the soil samples were found to be 2.94 Cmolkg⁻¹ (table 3) in both sampling areas. Calcium has a major role in the formation of cell wall membrane to keep the plant upright. Its deficiency results in poor growth, stunted roots and damage to fruits. The result of the study indicates that the areas are not deficient in calcium content.

The magnesium (Mg) content of the soil samples showed moderate values in both sampling areas. In Logo LGA, 2.65 Cmolkg⁻¹ was recorded while 2.64 Cmolkg⁻¹ (Table 3) was recorded for Ukum, all of which falls within the prescribed limit. Magnesium plays a major role in photosynthesis as it is the central atom of chlorophyll. It also acts as co-factor in several enzymatic reactions that activate the phosphorylation (Okoro *et al.*, 2021) ^[17].

The sodium (Na) contents of the study areas were found to be numerically the same 0.24 Cmolkg⁻¹ in both Logo and Ukum LGA. Higher values of sodium can result to stunted growth and reduction in cell development it can also cause tissue dry out in plans. The sodium content of the soil samples in both areas is suitable for agriculture, as it aligns with the standard ratings for Nigerian soil and other relevant regulatory bodies like the United States Department of Agriculture soil standard ranges.

4. Conclusion

The results of the study revealed that the soils of the study areas are sandy, slightly acidic, and possess good physical and chemical properties, making them suitable for supporting the growth of various crops. The low CEC values indicate a limited capacity for nutrient retention. Therefore, the use of fertilizers is recommended to enhance soil efficiency.

5. Conflict of Interest

The authors declare no conflict of interest.

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