FUDMA Journal of Sciences (FJS)
ISSN online: 2616-1370
ISSN print: 2645 - 2944
Vol. 9 No. 12, December (Special Issue), 2025, pp 408 – 416
DOI: https://doi.org/10.33003/fjs-2025-0912-4433

# AN EVALUATION OF FERTILITY CAPABILITY CLASSIFICATION OF MBAMBA SOILS IN YOLA SOUTH LOCAL GOVERNMENT AREA NORTH-EASTERN NIGERIA

**[1]Jungudo Muhammed Bashir and *[2]Abdulqadir Abubakar Sadiq**

[1]Department of Horticulture, College of Agriculture, Science and Technology, Jalingo, Taraba State
[2]Department of Agricultural Technology, Adamawa State Polytechnic, Yola

*Corresponding authors' email: sadiqhsadiq6@gmail.com Phone: +2347068036372

**ABSTRACT**

Understanding soil fertility capability status is considered as one of the most important tool towards improving and managing soil nutrients for profitable and sustainable farming. This study aimed to evaluates fertility capability classification of Mbamba soils in Yola South Local Government Area North-eastern Nigeria. Three (3) profile pits were dug based on the topo-sequence variation where core soils samples of the soils were collected from the identified distinct horizons. The results revealed that fertility capability classification (FCC) of the soils at profile 1 and 3 was classified as LLdn$^-$km dominated with loamy soil developed under ustic moisture regime having 6-15 % Na saturation, low nutrient reserve and organic matter. In addition, at profile 3 site of the area it was classified as SLdn$^-$km characterized as soil dominated with sandy texture at surface and loamy at subsurface horizons with low nutrient reserve, low exchangeable cation exchange capacity and organic matter content. Generally, the soils were classified as low fertility capability soils to support effective crop growth and development. Therefore, there is ardent need for the farmers in the area to employ integrated nutrients management techniques with the aim of improving and sustaining the soil nutrients for sustainable food production in the area.

**Keywords**: Capability, Classification, Evaluation, Fertility, Soil

## INTRODUCTION

The major challenges in the 21st century are food security, environmental quality and soil health (Patil *et al.,* 2017). Besides, shrinking land holding and increasing cost of inputs necessitate induction and adoption of scientific use of plant nutrient for sustaining higher crop productivity. Soil is a vital resource which can be termed as "Soul of infinite life." Soil serves as the natural habitat of organisms and it is the medium through which plants obtain their nutrients (Oklo, *et al.,* 2021). It regulates plants growth, water contents, recycles raw materials etc. Achieving and maintaining optimal levels of soil fertility is of paramount importance if agricultural land is to continuously sustain crop production. Soil analysis has been used as an aid to assessing soil fertility, hence, the need for soil analysis. Therefore soil fertility is the major component of productivity which primarily deals with nutrient supplying ability of the soil to the plant (Patil *et al.,* 2017). Boskina, *et al.,* (2025) reported that Nwite and Okolo (2020) explained that in Nigeria, despite large production potential, yield gaps persist due to declining soil fertility, poor input use, and unsustainable farming practices Assessing soil fertility status is difficult because most soil chemical properties either change very slowly or have large seasonal fluctuations; in both cases, it requires long-term research commitment (Beyene, 2019).

The concept of soil fertility capability classification (FCC) system was developed in an attempt to bridge the gap between the sub-discipline of soil classification and soil fertility (Buol *et al,* 1975). The SFCC is a classification of soils on the basis of fertility constraints, quantified from condition modifiers (Rao and Jose 2003). The original version of SFCC (Buol *et al.* 1975) was modified to include specific interpretations for wetland rice soils (Sanchez 1997 and Sanchez *et al.,* 2003). The economic conditions of the farmers in the tropics force them to rely largely on organic inputs for managing soil fertility, with mineral fertilizer inputs playing a secondary role or no role at all (Palm *et al.* 2001). The FCC can be used for agronomic purpose as alternative methods for soil characterization and evaluation.

In Mbamba area of Yola South local government area peasant farmers are intensively cultivating arable lands and applying both organic and inorganic fertilizers without knowing the fertility capability and nutrients requirement and this does not give the expected yields. In addition, there is no research conducted in the area that classify fertility capability status of the soil in the area. Therefore, there ardent need to assess fertility capability of the soil in the area towards providing practical information for effective fertilizer recommendation and crop requirement for sustainable food production. Thus, this study aims to evaluate of fertility capability classification of some soils in Mbamba area of Yola South Local Government Area North-eastern Nigeria

## MATERIALS AND METHODS

### Study Area

The study was conducted in Mbamba area of Yola-South Local Government Area of Adamawa State, North-eastern Nigeria which lies at 9° 10' - 9° 11' North of the Equator and Longitude 12° 31' -12° 33' East of the Greenwich Meridian having an elevation ranges from 166-196 m (Sadiq and Vahyala, 2023). The area is located at the eastern part of Yola South LGA characterized by few tall trees and grasses. The farmers engaged dominantly in animal grazing and arable farming where rice and maize been the major crop grown for about 5-35 years' conservation farming experience (Sadiq and Shuwa, 2019). The steepness nature and variability of slope in the area coupled with excessive tillage led to development of gully erosion affecting the farmland. This result is in conformity with the recent findings of Sadiq, *et al.,* (2019a).

### Field Work

Three (3) profile pits were dug at the study site based on the topo-sequence variability where core samples of the soils were collected at the identified diagnostic horizons. The samples were transferred in to polythene bags and well labelled for further physical and chemical analysis in the laboratory

**Laboratory Analyses**

The soil samples collected were air-dried, and crushed using pestle and mortar to pass through a 2mm sieve, some of the samples were further passed through 0.5mm for chemical analysis. The soil samples collected were analyzed for their physical and chemical using standard laboratory procedures at the Department of Soil Science Laboratory, Modibbo Adama University Yola.

***Soil physical properties***

The particle size distributed was determined by the Bouyoucous hydrometer method (Jaiswal, 2003). The texture of the soil was determined by applying the particle size distribution data to the marshal's textural triangle. The bulk density was determined from undisturbed soil samples in the field using core samplers (Jaiswal, 2003). Soil porosity of the samples was determined as described by Jaiswal, (2003).

***Soil chemical properties***

The pH of the soil was measured in a 1:2 soil-water suspension ratio and also in 0.5M KCl solution using glass electrodes pH meter (Jaiswal, 2003). The electrical conductivity was measured alongside pH with an EC meter using the same soil-water suspension used for measuring the soil pH in water (Jaiswal, 2003). Organic carbon was determined by wet oxidation method of Walkley and Black, (1934). In this method organic carbon is oxidized by $K_2Cr_2O_7$ in the presence of $H_2SO_4$. Total nitrogen content of the soil was determined by the Kjeldahl's wet digestion method (Bremner, 1965). Available phosphorus content was determined by bicarbonate extraction method for near neutral and slightly alkaline soils while for acidic soils, the determination of available phosphorus was done by Bray No. 1 method (Jaiswal, 2003). The exchangeable cations were determined in the extract of 1N neutral ammonium acetate ($NH_4OAc$) (Jaiswal, 2003). The exchangeable calcium and magnesium content of soil were determined titrimetrically while the exchangeable potassium and sodium was determined by flame photometer. Total exchangeable acidity (TEA) was carried out by displacement with 1N KCl and titrating the extract with 0.025N NaOH solution using Phenolphthalien Indicator (Black 1965; Anderson and Ingram, 1993; Jaiswal, 2003). Cation Exchange Capacity was calculated by multiplying the Total Exhangeable Baes by Exchangeable Acidity (Jaiswal, 2003). The effective cation exchange capacity was determined by summing up all the exchangeable cations and the exchangeable acidity (Jaiswal, 2003). Base saturation was calculated by dividing the sum of the exchangeable bases by the CEC (soil) expressed as a percentage (Jaiswal, 2003):-

$$PBS = \frac{Ca, Mg, K, Na}{ECEC} \times 100$$

The ESP content was calculated by dividing the exchangeable sodium content of the soil by the CEC (soil) expressed as a percentage (Jaiswal, 2003):-

$$ESP = \frac{Na}{ECEC} \times 100$$

Some micronutrients determined include Cu, Fe, Mn and Zn – Fe was extracted with 1N acetic acid (pH 4.8), while Mn was extracted with 1N acetic acid (pH 7.0) as described by Jaiswal, (2003). Zn and Cu were extracted by diphenyl thiocarbazone complexing agent (Shaw and Dean 1952).

**Data Analysis**

***Descriptive Statistics***

Explanatory data analysis was performed using SAS (version 9.4) statistical software. The data distribution was analyzed by classical statistics (Mean, maximum, minimum).

**Soil Fertility Capability Classification (FCC) System**

The analyzed soil properties were classified using soil fertility capability classification (FCC) system adopted by Sanchez et *al.,* (2003).

**RESULTS AND DISCUSSION**

**Morphological Properties of the Study Area**

***Mbamba profile 1***

The morphological properties of the soil of Mbamba profile 1 study area are shown in Table 1. Mbamba profile 1 is on moderate to strong slopes of 6-13 %, imperfectly drained with the presence of moderately to severe erosion having no exposed bed rock to 2 %. The profile depicted three (3) distinct horizons. The results show a distinct variation of wet colour in the designated Ap and Bt1 horizons ranges from dark gray (10 YR 4/1), brown (10 YR 5/3) while in the Bt2 horizon were dominated with very dark gray coloration (10 YR 3/1). These variations might be credited to weathered materials in the area which exhibit these colorations of brown and gray. Petters (1995) described shale to produce black to dark grey materials. Consequently, soils derived from these materials exhibit these colorations. It could also be connected to the organic matter content of soil in the area exhibiting a wide range of dark brownish coloration. Mottles were observed in the Bt2 horizon (60-120 cm) having few fine distinct mottles. This finding suggests the existence of shallow subsurface ground water retention with increased profile depth which could be attributed to the textural transformation (of clay loam- sandy loam to sandy clay) during pedogenesis process. Moderate, medium sub-angular blocky structure was identified in the Ap horizon (0-30 cm) while in the three subsurface layers; weak fine sub-angular blocky was observed. At the Ap horizon of 0-25 cm wet consistence of non-sticky and non-plastic, very friable when moist and hard under dry condition were observed while slightly sticky, slightly plastic wet consistency were identified at the Bt1 horizon (30-60cm) with firmly at moist and hard when dry consistence was observed. In addition, at the Bt2 horizon of 60-120 cm with very sticky, very plastic in wet condition, very firmly when moist and hard consistencies were observed. This trend of consistency variation within the horizon might be linked to textural variations across the pedon. The trend may further explain the increase of fine loamy particles with increasing soil depth due to the translocation effects of illuvial processes in the arable soils. This finding agreed with outcome of Nsor and Iibanga (2008) work that there was a progressive increase in loam with depth in all the pedons studied Presence of few fine roots at the two upper layers (0-25 cm and 25-60 cm) were observed while at the last horizon 60-120 cm was observed to have few fine concretions were noted. The restriction of roots below the plough layer indicates the intensive arable activities with little or no higher plants populations due to intensive deforestation practices by the farmers in the area.

***Mbamba profile 2***

Mbamba profile 2 profile shows three distinct horizons (ranges from 0- 120 cm) sited on gentle 2-6 % slopes, well drained and cultivated lands (Table 1). The morphological properties were observed where wet colourations in all the horizons ranging from brown (7.5 YR 4/4 for Ap), strong brown (7.5 YR 4/6 for Bw1) to dark brown (7.5 YR ¾ for Bw2) respectively. The trends remained similar in dry condition having strong brown colour at Ap horizon (7.5 YR 4/6), light gray at Bw1 (7.5 YR 5/8) and light brown at Bw2 (7.5 YR 4/6), respectively. Different parent materials exhibit different coloration as well as their weathered products.

However, mottles were recognized at Bw2 horizon with few fine distinct feaatures which could be ascribed to the presence of high accumulation or retention of water in the horizons during the rainy season. In addition, sandy loam texture dominated all the horizons of the profile except at the uppermost horizon layer having loamy sand. Suharta (2010) stated that hard soil texture (sand dominance) leads to the low ability of the soil to retain water and nutrients, and the soil becomes prone to drought and sensitive to erosion.

Weak fine sub-angular blocky structure was recognized at Ap horizon followed by moderate medium sub-angular blocky structure in the Bw1 horizon and in Bw2 horizon weak fine sub-angular blocky structure was recognized. This result is in conformity with report of Anne, *et al.,* (2015) who also observed that the soils of Mwala District, with very deep profile (>120cm) have weak fine sub-angular blocky structure with dark brown to strong brown colours. Similar soil consistency of non-sticky, non-plastic, loose and hard when dry was observed in all the horizons. The observed uniformity of soil consistency in the entire horizon could be atributed to the homogeneity of the soil texture. Few fine roots were observed in Ap and Bw1 horizons while few fine gravels in Bw2 horizon were observed (95-120 cm) respectively.

***Mbamba Profile 3***

The morphological properties of the soil profiles are shown on Table 1. Mbamba Profile 3 is on moderate to strong slopes of 6-13 % with moderate to severe soil erosion having no bed rock exposed. It shows three distinct horizons ranging between 0 and 140 cm depths. In Ap horizon the wet colour was found to be 10 YR 4/3 (brown) then varied from to dark yellowish brown (10 YR 4/6) at Bw1 to brown (10 YR 5/2) at the Bw2 horizon. Dry colouration varied from (10 YR 5/2) at Ap horizon defined as grayish brown, yellowish brown (10 YR 5/6) at Bw1 to grayish brown of 10 YR 5/2 in the Bw2 horizon respectively. The soils derived from basalt parent material were all reddish brown, dark reddish brown, bright reddish brown and bright brown (Nsor and Ibanga, 2008). At the Ap and Bw1 horizons no mottle was identified while at the last horizon (69-140 cm) few fine faint mottles were observed.

Similarly, homogeneous soil texture of sandy loam was observed in the Ap and Bw1 horizons while at the last horizon (Bt) sandy clay loam texture was identified. The profile was at the strong slopes (> 10 %) toposequence with severe soil erosion process. Amalu, (1998) explained that most soils exhibit variable soil texture at the topsoil layers with an increasing fineness with depth. The structure of the soils was weak, fine sub-angular blocky on the surface then transformed to strong moderate medium sub-angular due to sand illuviation in the Bw1 horizon and in the Bw2, weak fine sub-angular blocky. The dry consistency of the surface soil is slightly hard while the sub-soils are hard to very hard. In addition, in the Ap and Bw1 horizons (Ap and Bw) were assessed, have non sticky, non- plastic when wet, very friable at moist and hard when dry consistencies. In contrast, very sticky, very plastic when wet, very firm at moist and soft when dry consistencies were observed at the Bt horizon (69-140 cm) due to increase of clay content down the profile. In addition, the presence of few fine roots was observed in the upper layers (0-24 cm and 24-69 cm) followed by few fine concretions in the lowest profile depth (69-140 cm). The limited root in the sub-soil layers indicated that the shrubs vegetation above the ground were rare. Thus, the physiographic features of the area were characterized by few tall trees and grasses.

**Soil Physical Properties of the Mubi North LGA**

***Soil texture***

Results of physical properties of the studied soil are presented on Table 2. It was revealed that the sand content decreased down the profile in all the studied areas. The presence of high sand content in all pedons particularly at upper horizons indicates the soil to have high water permeability. High permeability of water might reduce the affinity of the soil to reserve or retain nutrient due to low CEC and OM of the soil. This is because low CEC soils values are usually found in very low clay soil and organic matter contents of the soils. The coarse texture of sandy loam control the variability of nutrient storage capacity, limit the water holding capacity and roots may grow under sub-optimal soil water due to water deficits (Gachene and Kimaru, 2003; Anne, *et al.,* 2015). Soil texture is the most stable physical characteristic of the soils which has influence on a number of other soil properties including structure, soil moisture availability, erodibility, root penetration and soil fertility (Landon, 1991; Msanya *et al.,* 2003; Anne, *et al.,* 2015).

***Bulk density***

The bulk density of the soil ranges from medium to high (1.42-1.63 g/cm$^3$). It could be explained that the high bulk density of the soil at the Ap horizon could be connected to the agronomic activities such as intensive tillage practices using tractors which tends to increase the compaction of the soil, thus, reducing porosity and infiltration. These finding concords with the result of Azooz and Arshad, (1996) that tilled soils under continuous cultivation tend to become less porous and more-dense with time in the plow layer. Therefore, long-term conventional tillage and no-tillage systems can alter bulk density, aggregate stability, total porosity and organic carbon content (Singh *et al.,* 1994). Secondary tillage (cultivation) generally decreases pore space and thus increase bulk density which stands as a reason for the high bulk densities of cropped soils (Mulugeta and Sheleme, 2011).

Hence, soil bulk density indicates the compactness of the soil (Debela, *et al.,* 2011) which may affect root penetration of crops. However, an increase in the bulk density is not necessarily detrimental to crop growth, because at certain limits ((1.5-2.0 g/cm$^3$) this increase may contribute to soil water storage and load support ability when trafficked with machines or animal trampling (Reichert, *et al.,* 2009).

***Total porosity***

The total porosity of the soil was highest at pit 1, 2 and 3 with the corresponding values of 46.24 %, 45.73 % and 42.64 % respectively. These variations of total porosity could be attributed to the bulk density of the soil. For any given soil, the higher the bulk densities, the more compacted the soil is and the lower the pore space (Anne *et al.,* 2015).

**Table 1: Morphological properties of the studied profile of the study area**

| | Depth (cm) | Horizon Designation | Wet Colour | Dry Colour | Mottles | Textural Class | Structure | Consistence | Roots | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|
| | 0-25 | Ap | 10 YR 4/1 | 10 YR 5/2 | N | SL | M,m,sbk | Wns,np, Mvfr, Dh | Rff | Moderate to strong slopes (6-13 %) |
| MBA 1 | 25-60 | Bt1 | 10. YR 5/3 | 10 YR 6/3 | N | SCL | W,f,sbk | Wss,sp, Mf, Dh | Rff | Imperfectly drained |
| | 60-120 | Bt2 | 10 YR 3/1 | 10 YR 5/3 | Ffd | SCL | W,f,sbk | Wvs,vp, Mvf,Dh | Cff | No bed rock exposed to 2 % |
| MBA 2 | 0-30 | Ap | 7.5 YR 4/4 | 7.5 YR 4/6 | N | LS | W,f,sbk | Wns,np,Mvfr,Dh | Rff | No bed rock exposed to 2 % |
| | 30-95 | Bw1 | 7.5 YR 5/8 | 7.5 YR 4/6 | N | SL | M,m,sbk | Wns,np,Mvfr Dh | Rff | Imperfectly drained and uncultivated |
| | 95-120 | Bw2 | 7.5 YR 3/4 | 7.5 YR 4/6 | Ffd | SL | W,f,sbk | Wns,np, Mvfr, Dh | Gff | Gentle land 2-6 % slopes |
| MBA 3 | 0-24 | AP | 7.5 YR 4/3 | 10 YR 5/2 | N | SL | W,f,,sbk | Wss,sp, Mfr, Dh | Rff | Moderate to severe erosion (6-13 % slope) |
| | 24-69 | Bw | 10 YR 5/6 | 10 YR 4/6 | N | SL | M,m,sbk | Wss, sp, Mfr,Dh | Rff | Rice, maize and groundnuts cultivation |
| | 69-140 | Bt | 10 YR 5/2 | 10 YR 4/3 | Fff | SCL | W,f,sbk | Wvs,vp, Mvf, Ds | Cff | No bed rock and moderately drained |

Key: N : None, Ffd : Few fine distinct, Fff: Few fine faint, M,m,sbk: Moderate medium sub angular block, W,m,sbk: Weak medium sub angular block, W,f ,sbk: Weak fine sub angular blocky, Wns, np, Mvfr, Dh: Wet non-sticky, non-plastic, Moist very friable, Dry had, Wss, sp, Mf, Dh: Wet slightly sticky, slightly plastic, Moist friable, Dry hard. Wvs, vp, Mvfr, Dh: Wet very sticky, very plastic, Moist very friable, Dry hard, Wvs, vp, Mvfr, Ds: Wet very sticky, very plastic, Moist very friable, Dry soft, Rff: Root few fine, Gff: Gravel few fine, Cff : Concretions few fine.

**Table 2: Physical Properties of the studied soils**

| Location | Horizon Designation | Depth | Sand | Silt | Clay | TC | Bd (g/cm$^3$) | Pd (g/cm$^3$) | TP (%) |
|---|---|---|---|---|---|---|---|---|---|
| | Ap | 0-25 | 61 | 20 | 19 | SL | 1.46 | 2.66 | 45.00 |
| | Bt1 | 25-60 | 54 | 24 | 22 | SCL | 1.42 | 2.35 | 39.57 |
| MBA 1 | Bt2 | 60-120 | 60 | 17 | 23 | SCL | 1.43 | 2.66 | 46.24 |
| | Ap | 0-30 | 88 | 4 | 8 | LS | 1.63 | 2.50 | 34.80 |
| | Bw1 | 30-95 | 68 | 16 | 16 | SL | 1.49 | 2.50 | 40.40 |
| MBA 2 | Bw2 | 95-120 | 64 | 16 | 20 | SL | 1.57 | 2.50 | 37.20 |
| | Ap | 0-30 | 72 | 12 | 16 | SL | 1.50 | 2.45 | 38.77 |
| MBA 3 | Bw | 30-71 | 68 | 20 | 12 | SL | 1.54 | 2.66 | 42.10 |
| | Bt | 71-130 | 54 | 24 | 22 | SCL | 1.42 | 2.35 | 39.57 |

Key: TC= Textural class, Bd= Bulk density= Pd= Particle density, TP= Total Porosity

**Soil Chemical properties of the study Area**

***Soil pH***

The results on soil pH are presented in Table 3. The results shows that the soil reaction of Mbamba profile 1area ranges from 6.30 to 6.80 described as slightly acidic in all pedons with the highest value in Ap horizon. Conversely, at Mbamba profile 2 area the soil pH varies from 6.80 to 7.60 considered as slightly acidic to slightly alkaline with the highest value of 7.60 in Bw2 horizon. The slightly acidic reaction of the soil could be attributed to the use of inorganic fertilizers and herbicides on the farmlands. This assertion was also buttressed by the report of Igboekwe and Adindu, (2011). Soil pH is influenced by the response of different nitrogenous fertilizer absorption and releases of nutrients at the soil water interface (Mahajan and Billore, 2014).

Similarly, slightly acidic soil reaction was found at Mbamba profile 3area in all the identified pedons ranges from 6.5 to 6.8 with the highest value at the second horizon. At Mujilu area the pH values ranged from 5.50 to 7.90, the lowest pH values of 5.50 dS/m was recorded in the Bt horizon and the highest value of 7.90 was found in Bw1 horizon.

***Electrical conductivity***

Electrical conductivity (EC) is a measure of the concentration of water soluble salts in saturated soils. The results on Table 4 shows that the EC values of Mbamba profile 1 vary from 0.03 to 0.09 dS/m while profile 2 showed values of 0.03 to 0.22 dS/m which may be connected to sandy textural variation in all the pedons which permits free flow ions through leaching process. The EC values at profile 3 varied from 0.03 to 0.8 dS/m. It could be explained that the EC values in all the pedons of the study area were within the normal range of less than 1 dS/m which is considered non-saline and suitable for plants growth and soil microbial processes.

***Soil organic matter***

The results of the soil organic matter (Table 3) shows very low values for Mbamba profile 1 in all the designated Ap, Bt1 and Bt2 horizons with values of 9.30 g/kg, 8.60 g/kg and 6.2 g/kg. These results clearly indicate decrease of OM content down the profile. Liu *et al.,* (2017) and Liu, *et al.,* (2019) suggested that above-ground and underground plant biomass in native vegetation land provided leaf litter and root exudates that can increase soil organic matter (SOM). For pit 2, the OM content was moderate to low with values of 26.8 g/kg in Ap horizon, 21.70 g/kg in Bw1 and 15.1 g/kg Bw2 horizon. Decreased organic matter content with depth was also evident in pit 2 as was also reported by Tekwa *et al.,* (2013). Low to very low OM content was found at pit 3 which varies from 14.8 g/kg at Ap horizon, 12.7 g/kg at Bw horizon and very low value of 8.3 g/kg at Bt horizon. The observed gradual decrease of OM content within the soil horizons could be linked to the presence of more decomposable organic material such as leaves, litters, and roots at upper surface layer which decrease with depth.

***Total nitrogen***

The total nitrogen (TN) content of the soil of pit 1 varied from 0. 4-0.50 g/kg with the lowest value in the Bt 1 horizon (0. 40 g/kg) while in pit 2 it ranged from 0.9-1.6 g/kg with the highest value of 1.60 g/kg in the Ap horizon (Table 3). The total nitrogen contents in all the soil pedons are low. Total nitrogen content was observed to be low in all the three pedons of pit 3 with values of 0.90 g/kg in Ap horizon, 0.70 g/kg in Bw and 0.50 g/kg in Bt horizon. It was also noted that total nitrogen content decreased down the profile.

***Available phosphorous***

The available phosphorous content of the studied area are also presented in Table 3. The results showed that the available phosphrous was generally low and ranged from 6.59 to 10.41 mg/kg. At pit 1 the available phosphorous content was highest at Bt1 horizon (10.41 mg/kg) with the lowest value of 6.59 mg/kg recorded in Bt2 horizon. Pit 2 values ranged from 8.50 mg/kg to 9.94 mg/kg with Bw1 having the lowest value. In addition, pit study area also showed low value of available phosphorous ranges from 9.69-9.83 mg/kg with the highest value of 9.83 mg/kg in Bw horizon which might be linked to the high OM content in the pedon than the other pedons in the profile. Thus, this is a clear indication that OM content play a vital role towards improving and increasing the available phosphorous in the soil. This assertion was also buttressed by the report of Adisa *et al.,* (2016).

***Potassium***

Potassium contents of the studied soils are presented in Table 3. The results showed that at pit 1 area the potassium content was highest in Bt1 horizon with a recorded value of 1.08 cmol/kg and the lowest value was found in Bt2 horizon. This finding correlates with the results of Tekwa *et al.,* (2011) and Sadiq and Tekwa, (2022) that available potassium (K) content is rated as moderate to high and it generally decreases with soil depth. Meanwhile, at pit 2 the potassium content was highest at the last horizon (0.72 cmol/kg) which might be influenced by high sodium value than other horizons. Furthermore, pit 3 area has an increase of potassium content with depth ranges from 0.23 cmol/kg in Ap horizon, 0.47 cmol/kg in Bw horizon and 0.81 cmol/kg in Bt horizon.

***Sulphur***

The sulphur content of soils of the study area is enerally considered as low to medium and varies from 6.50 mg/kg to 11. 30 mg/kg. Table 3 showed that sulphur content at pit 1 study area ranges from 6.50 mg/kg to 8.50 mg/kg with lowest (6.5 mg/kg) amount recorded in the last (Bt2) horizon which could be due to very low OM content present in the horizon.

Meanwhile, the highest sulphur value (8.5 mg/kg) was observed in Bt1 which could also be connected to the amount of organic matter. On the other hand, at pit 2 of Mbamba area the sulphur content decreases down the soil profile from 10.68 mg/kg in Ap horizon, 8.35 mg/kg in Bw1 horizon to 7.37 mg/kg in Bw2 horizon. This decrease of sulphur might be directly to decrease of OM content and total nitrogen content down the profile which clearly indicates the role and contribution of organic materials to sulphur variation in the soil. Similar trends were observed at pit 3 as the OM content and total nitrogen content decreases with depth (Table 3) which leads to the abrupt decline of sulphur content in all the horizons with the corresponding values of 10.33 mg/kg in Ap horizon, 8.25 mg/kg in Bw horizon and 7.45 mg/kg in the Bt horizon.

***Calcium***

The results revealed that the area relatively has sufficient Ca content ranging from 1.72 cmol/kg to 8.80 cmol/kg. For pit 1 area the Ca content gradually decreased with soil depth having a highest value of 8.80 cmol/kg in Ap horizon, 7.20 cmol/kg in Bt1 horizon and 4.60 cmol/kg in Bt 2 horizon. In pit 2 of the area the Ca content varies from 4.80 cmol/kg to 5.60 cmol/kg whicl is lower than the profile 1. In addition, at pit 3 area the Ca content recorded was low ranging from 2.91 cmol/kg in Ap horizon, 3.99 cmol/kg in Bw horizon and 2.47 cmol/kg in Bt horizon.

***Magnesium***

It was revealed that at profile 1 Mg content increases with depth with recorded values of 1.20 cmol/kg in Ap horizon, 1.60 cmol/kg in Bt1 and 3.10 cmol/kg in Bt2 horizon respectively. In contrast, the lowest magnesium value was found in last (Bw2) horizon in profile 2 with a value of 1.60 cmol/kg. The occurrence of lowest Magnesium content in upper layer of pit 1 might be attributed to magnesium mining by the root uptake of crops coupled with rapid leaching of magnesium at upper layer due to sandy loam textured soils down to the less porous sandy clay loam textures of the last two horizon and poor management under the traditional farming system. Nutrient depletion or loss has been reported under the traditional farming system (Agboola and Shittu, 2002).

At pit 3 area, the magnesium values varies within the identified three horizons with corresponding values of 1.44 cmol/kg in Ap horizon, 2.55 cmol/kg in Bw horizon and lowest value of 1.13 cmol/kg in Bt horizon. The lowest value of magnesium in Bt horizon could be connected to textural variations from coarser (sandy loam) at the Ap horizon to more finer (sandy clay loam) at Bt horizon which allow rapid leaching process.

***Sodium***

The result revealed that the sodium content of the soils at profile 1 increased with depth in all the horizons except in the Bt2 horizon which declined to 0.74 cmol/kg. In contrast, in profil 2 site sodium content decreased in all the horizons with corresponding values of 0.74 cmol/kg in Ap horizon, 0.93 cmol/kg in the Bw1 horizon and 1.22 cmol/kg in Bw2 horizon. Increased sodium content down the profile could be connected to the leaching effects of sodium due to high rainfall intensity experienced in the area coupled with macro-porosity of the dominated sandy textural class of soil which allow rapid permeability of water down the profile. Moraru *et al.,* (2020) found that soils with fine textures have a very low–medium drainage capacity while soils with sandy and medium textures, generally, have a high–very high drainage capacity which will allow ease and free movement of sodium ions. Similarly, at pit 3 area it was found that sodium content increases with soil depth in all the designated Ap, Bt and Bw horizons (Table 4) determined values of 0.07 cmol/kg, 0.61 cmol/kg and 1.24 cmol/kg.

***Total exchange acidity***

The TEA was generally rated as low ranging from 0.50cmlo/kg to 1.87 cmlo/kg. The results revealed that TEA at profile 1 area decreases with depth with the values of highest value of 1.87 cmol/kg in the Ap horizon, 1.15 cmol/kg in Bt1 horizon and 0.45 cmol/kg in Bt2 horizon respectively. The decrease of TEA down the profile might be attributed to decrease of aluminum and hydrogen ions down the profile. Meanwhile, in profile 2 TEA was highest in Bw1 horizon with 1.69 cmlo/kg. Likewise, at profile 3 the TEA was lowest in Bw horizon due to the lowest aluminum and hydrogen contents.

***Cation exchange capacity and effective cation exchange capacity***

The results of the Cation Exchange Capacity and Effective Cation Exchange Capacity (ECEC) presented in Table 3 generally described the soils of the area as having low to moderate values. The values of the respective areas revealed that CEC values at profile 1 ranged from 9.47 cmlo/kg to 12. 88 cmlo/kg, which decreased down the profile. This decreased of CEC within the soil profile might be attributed to the decreased of OM content with depth. Landon, (1991) explained that decrease in CEC levels in soil may be influenced by decreased in soil organic matter content. Similar trend was observed at pit 2 of the area where the CEC was greater in the Ap and Bt1 horizons (9.29 cmlo/kg and 11.87 cmlo/kg) where the OM content was moderate while the lowest value (9.02 cmlo/kg) was recorded in the Bt2 horizon with lowest OM content. This buttressed the conclusion drawn by Ashenafi *et al.* (2010) from their study at the Delbo Wegene Watershed that CEC of the soils were generally higher in the surface than in subsurface horizons which could be due to the strong association between organic carbon and CEC of the soil. Conversely, the ECEC decreased down the profile at profile 3 and ranged from 6.88 cmol/kg to 21.04cmol/kg. This could be attributed to leaching, high sand content, extensive and continuous cultivationof the soil in the area.

***Percent base saturation***

The percentage base saturation of the study area was generally rated as high with values ranging from 83.12 % to 89.95 %. The value of PBS was greater in Bt1 horizon for profile 1 with a value of 89.95 % while in profile 2 the highest value was observed in the last Bw2 horizon. Thus, availability of basic cations increased with increase in base saturation due to reactions that exist in the soil solution. Ashenafi *et al.* (2010) from their study at the Delbo Wegene Watershed reported that exchangeable cations content of the soils increased with increasing soil depth. The increment was attributed to the leaching of exchangeable cations. Moreover, at profile 3 the PBS value of 85.67 % was recorded in all the three identified horizons

**Table 3: Chemical characteristics of the studied soils**

| Location | Horizon | Depth | pH | EC | Org.C | Org.M | TN | Av-P | S | $Ca^{2+}$ | $Mg^{2+}$ | $Na^{+}$ | $K^{+}$ | TEB | H | $Al^{3+}$ | TEA | CEC | ECEC | PBS | ESP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | (cm) | (cm) | (1:2) | (dS/m) | → | g/kg | ← | (mg/kg) | (mg/kg) | → | | | | cmol/kg | ← | | | | | % | % |
| | Ap | 0-25 | 6.80 | 0.09 | 5.40 | 9.30 | 0.50 | 8.74 | 7.80 | 8.80 | 1.20 | 0.78 | 0.23 | 11.01 | 0.74 | 1.13 | 1.87 | 12.88 | 6.88 | 88.72 | 6.09 |
| MBA 1 | Bt1 | 25-60 | 6.30 | 0.03 | 5.00 | 8.60 | 0.40 | 10.41 | 8.50 | 7.20 | 1.60 | 0.86 | 1.08 | 10.74 | 0.42 | 0.73 | 1.15 | 11.89 | 10.23 | 89.95 | 7.24 |
| | Bt2 | 60-120 | 6.60 | 0.03 | 3.60 | 6.20 | 0.50 | 6.59 | 6.50 | 4.60 | 3.10 | 0.74 | 0.59 | 9.03 | 0.10 | 0.34 | 0.45 | 9.47 | 21.04 | 85.67 | 7.80 |
| | Ap | 0-30 | 6.80 | 0.03 | 15.60 | 26.80 | 1.60 | 9.94 | 10.68 | 4.80 | 2.40 | 0.74 | 0.67 | 8.61 | 0.21 | 0.47 | 0.68 | 9.29 | 13.66 | 85.50 | 7.96 |
| MBA 2 | Bw1 | 30-95 | 6.50 | 0.03 | 12.60 | 21.70 | 1.30 | 8.50 | 8.35 | 5.60 | 3.60 | 0.93 | 0.05 | 10.18 | 0.66 | 1.03 | 1.69 | 11.87 | 7.02 | 84.98 | 7.84 |
| | Bw2 | 95-120 | 7.60 | 0.22 | 8.80 | 15.10 | 0.90 | 9.94 | 7.37 | 4.80 | 1.60 | 1.22 | 0.72 | 8.34 | 0.29 | 0.39 | 0.68 | 9.02 | 13.26 | 87.42 | 13.50 |
| | Ap | 0-24 | 6.70 | 0.03 | 8.60 | 14.80 | 0.90 | 9.69 | 10.33 | 2.91 | 1.44 | 0.07 | 0.23 | 4.65 | 0.66 | 1.03 | 1.69 | 6.34 | 3.75 | 85.67 | 1.14 |
| MBA 3 | Bw | 24-69 | 6.80 | 0.08 | 7.40 | 12.70 | 0.70 | 9.83 | 8.25 | 3.99 | 2.55 | 0.61 | 0.47 | 7.61 | 0.13 | 0.37 | 0.50 | 8.11 | 16.22 | 85.67 | 7.47 |
| | Bt | 69-140 | 6.50 | 0.07 | 4.80 | 8.30 | 0.50 | 9.69 | 7.45 | 2.47 | 1.13 | 1.24 | 0.81 | 5.65 | 0.50 | 1.14 | 1.64 | 7.28 | 4.43 | 85.67 | 17.00 |

**Table 4: Fertility Capability Classification of the Studied Soils**

| Location | Type | Sub-type | Condition modifiers | | | | | | FCC Class | Interpretation | Management practices |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | D | R | $n^-$ | k | E | M | | | |
| MBA 1 | L | L | * | - | * | * | - | * | LLd$n^-$km | Loamy surface and loamy sub surface formed under ustic moisture regime, with 6-15 % Na saturation, having low nutrient reserve with low ECEC and low organic carbon saturation. | Conservational tillage and integrated nutrient management may be adopted for sustainable production. |
| MBA 2 | S | L | * | - | * | * | - | * | SLd$n^-$km | Sandy surface and loamy sub surface formed under ustic moisture regime, with 6-15 % Na saturation, having low nutrient reserve with low ECEC and low organic carbon saturation. | Good residue management and integrated nutrient management (manure and inorganic fertilizers) |
| MBA 3 | L | L | * | - | * | * | - | * | LLd $n^-$km | Loamy surface and loamy sub surface formed under ustic moisture regime, with 6-15 % Na saturation, having low nutrient reserve with low ECEC and low organic carbon saturation. | Conservational tillage and integrated nutrient management may be adopted |

=Presence of condition modifiers

***Exchangeable sodium percentage***

The ESP in the area was generally rated low (< 15 %) ranging from 1.32 % to 13.59 %. The trend of the result showed increase of ESP in all the profiles which could be attributed to the downward increase of sodium content. In addition, at profile 1, the downward increased of ESP range from 6.09 % to 7.80 %, profile 2 ranges from 7.96 % to 13.50 % and Muchala 1.14 % to 17.00 %. Ahukaemere *et al.,* (2016) explained that low to medium sodium content may lead to decreased ESP of the soil.

***Fertility capability classification (FCC) of soils of the study area***

The fertility classification presented in Table 4 revealed that profile 1 and 3, had loamy texture (L) for type and subtype with condition modifiers of ustic moisture regime (d) with 6-15 % Na saturation ($n^-$) having low nutrient reserve (k) with low ECEC and low organic carbon saturation (m). Thus, classified as LLd$n^-$km in Soil Fertility Capability Classification System. Hussain, (2004) reported that savannah soils are generally low in inherent fertility. At pit 2 area sandy texture (S) for type and loamy(L) subtype at the subsurface horizon having ustic moistunre regime condition modifiers (d) with 6-15 % Na saturation ($n^-$) having low nutrient reserve (k) with low ECEC and low organic carbon saturation (m) of < 80 % in the top soil as shown on Table 16. Thus, classified as SLd$n^-$km.

**CONCLUSION**

The study evaluates the fertility capability classification of Mbamba soils in Yola South Local Government Area of North-eastern Nigeria. The soils was generally classified to have low fertility capability due low nutrients contents which in consequence reduce their productivity. Therefore, there is to improve optimum soil nutrient availability through effective nutrient management practices. This is because failure to improve or sustain the productive capacity of the inherently fragile soils, may distort the required supply of food and fiber that could satisfy the human teaming population in the area.

**REFERENCES**

Adisa, K. F., Ojetada, J. O., Muda, S. A. and Amusan A. A. (2016). Characterization and fertility capability classification of the soils of Shasha River Floodplain, Osun State Nigeria. *Ife journal of Agriculture.* Vol. 28 (1) pp20-34.

Agboola, A. A. and Shittu, O. S. (2002). Farming systems in Nigeria. In: Agboola, A. A. (ed) *Essentials of Agricultural Production in Nigeria*, 1st edition. Green Line Publishers, Ado-Ekiti pp 240.

Ahukaemere, C. M., Onweremadu, E.U., Akamigbo, F. O. R., and Ndukwu, B. N.(2016). Suitability evaluation of soils of the Coastal plain Sands for rain fed maiz production in acid Sands of South Eastern Nigeria. *Nigerian journal of soil science* 26, 138-145

Anne N. K, Charles K. K. G, Balthazar M. M, Peter W. M, Nyambilila A and Patrick T. G. (2015). Soil Morphology, Physico - Chemical Properties and Classification of Typical Soils of Mwala District, Kenya. *International Journal of Plant & Soil Science4 (2): 156 170, 2015; Article no. IJPSS.2015.017ISSN: 2320-7035* SCIENCEDOMAIN*international* www.sciencedomain.org

Amalu, U. C. (1998). Evaluation of properties of selected soils of Cross River Area and their management for increase cassava yield. *Global Journal of Pure and Applied Sciences, 4 (3): 243-249*

Ashenafi Ali, Abayneh, E, and Sheleme, B. (2010). Characterizing soils of DelboWegene watershed, Wolaita zone, Southern Ethiopia for planning appropriate land management. *Journal of Soil Science and Environmental Management*. 1(8), 184-199.

Azooz, A.H. and Arshad, M.A. (1996). Soil infiltration and hydraulic conductivity underlong-term no-tillage and conventional tillage systems. *Can. J. Soil Sci.* 76: 143-152.

Beyene, D. (2019). Fertility Evaluation of Soil For Cereal Production.*Global Scienctific Journals. GSJ: Volume 7, Issue 3, March 2019, Online: ISSN 2320-9186 . PP. 1007-1037* www.globalscientificjournal.com

Boskina, Y, Michael, C.G., Mamman A, Kefas, P.K., Manga, A.B. and Habila, R.A. (2025). effects of organo-mineral fertilizers on growth and yield of four upland rice cultivars in two locations in Taraba State, Nigeria. *FUDMA Journal of Sciences (FJS). Vol. 9 No. 7, July, 2025, pp 201 – 206* https://doi.org/10.33003/fjs-2025-0907-3325. *ISSN online: 2616-1370 . ISSN print: 2645 - 2944*

Bremner, J. M. (1965). *Total nitrogen in Methods of soil analysis part* 2, 1149 – 1178, Madison, WC. American Society of Agronomy.

Buol SW, Sanchez PA, Cate Jr RB, Granger M (1975). Soil Fertility Capability Classification: A technical soil classification system for fertility management. *In:* E. Bornemisza and Alvarado, A. (eds) *Soil management in Tropical America*. North Carolina State University, Raleigh, North Carolina.

Debela, H., Jesse, T.N., Zemede, A., and Nyangito, M.M. (2011). Physico-chemical soil properties of semiarid Ethiopia in two land use systems: Implications to crop production. *International Journal of Agricultural Research*. 6:12: 840-847.

Gachene, C.K.K. and Kimaru, G. (Eds.) (2003). *Soil fertility and Land productivity*: A guide for extension workers in the Eastern Africa Region. RELMA Technical Handout Series 30. Nairobi, Kenya: Regional Land Management Unit (RELMA), Swedish International Development Cooperation Agency (SIDA). Pp.164.

Hillel, D. (1980). Fundamentals of Soil Physics. Academic Press, Inc., London.

Hussain, M.M. (2004). Characterization and Classification of some Intensively Cultivated soil from the Ganges River Floodplain of Bangladesh. Dhaka Univ. *Journal of Biological Science*, 20:71-80

Igboekwe, M. U. and Adindu, R. U. (2011). Groundwater Recharge through Infiltration Process: A case study of Umudike, Southeasern Nigeria. *Journal of Water Resource and Protection,* 3: 295 – 299.

Jonh, L. H., Samuel, L. T. James, B. D., and Werner, L. N. (2006). *Soil fertility and fertilizers*: An introduction to nutrient management. 7th by Prentice Hall publishing co-Ltd. New-Delhi 110, 017 India Pp. ix, 98, 102, 164, 203, 293-360, 412-414, 447, 448 and 456.

Jaiswal, P.C. (2003). *Soil, Plant and Water Analysis*.Kalyani Publishers, Ludhiana, New Delhi, Norda Hyderabab, India. Pp.1-399.

Landon, J.R. (1991). *Booker Tropical Soil Manual.* A hand book for survey and agricultural land evaluation in the tropics and sub-tropics. 1st edition. N.Y, John Wiley and Sons Inc. 605 Third Avenue. New York. USA. P. 474.

Liu, M., Guilin H. and Qian Z.(2019). Effects of Soil Aggregate Stability on Soil Organic Carbon and Nitrogen under Land Use Change in an Erodible Region in Southwest China.*International Journal of Environmental Research and Public Health 16 (20):3809.*

Liu, M., Han, G.L., Li, Z.C., Liu, T.Z., Yang, X.M., Wu, Y.T., and Song, Z.L. (2017). Effects of slope position and land useon the stability of aggregate-associated organic carbon in calcareous soils. *Acta Geochim. 36, 456–461.*

Mahajan, S. and Billore, D. (2014). Assessment of Physico-chemical characteristics of the soil of Nagchoon Pond Khandwa, MP, India. *Research Journal of Chemical Sciences*. 4(1), 26-30.

Moraru, S.S., Ene, A., and Badila, A. (2020). Physical and Hydro-Physical Characteristics of Soil in the Context of Climate Change. A Case Study in Danube River Basin, SE Romania *Sustainability.* *www.mdpi.com/journal/sustainability PP 1.26*.

Mulugeta, D. and Sheleme, B. (2011). Characterization and classification of soils along the toposequence of Kindo Koye watershed in southern Ethiopia. MoA. Addis Ababa, Ethiopia. *East Africa Journal of Science.* 4 (2):65-77.

Msanya, B.M., Kaaya, A.K., Araki, S., Otsuka, H., and Nyadzi, G. I. (2003). Pedological characteristics, general fertility and classification of some benchmark soils of Morogoro District, Tanzania. *African Journal of Science and Technology, Science and Engineering Series. 4(2):101-112.*

Nwite, J. C. and Okolo, C. C. (2020). Enhancing rice productivity through soil fertility management in South-Eastern Nigeria. *International Journal of Agriculture and Rural Development*, 23(1), 5123–5130.

Nsor, M. E. And Ibanga, I. J. (2008). Morphological Characteristics and classification of soils derived from diverse parent materials in Central Cross River State, Nigeria.*Global Journal of Pure and Applied Sciences Vol. 14, No. 3, 2008: 271 - 277 Copyright (C) Bachudo Sciences Co. Ltd. Printed In Nigeria. ISSN 1118-0579*

Oklo, A.D., Armstrong, I.A., Idoko, O.M., Iningev, T.S., Emmanuel, A.A. and Oklo, R.O. (2021) Assessment of Soil Fertility in Terms of Essential Nutrients Contents in the Lower Benue River Basin Development Authority Project Sites, Benue State, Nigeria. Open Access *Library Journal 8: e7222.* *https://doi.org/10.4236/oalib.1107222*

Palm, C.A., Gachengo, C.N., Delve, R.J., Cadisch, G, and Giller, K.E., (2001). Organic inputs for soil fertility management in tropical agroecosystems: application of an organic resource database. *Agriculture, Ecosystems and Environment* 83, 27-42.

Petters, S. N., (1995). *South-Eastern Benue Trough and Ikom - Mamfe Embayment*. In: Geological Excursion Guide Book to Oban Massif, Calabar Flank and Manfe Embayment, Southern Nigeria, Dec Ford Publisher's Limited, Calabar.

Patil, A.H., Kumbhar, A.V ., Nale, V.N (2017). GIS-GPS Based Soil Fertility Maps of Agriculture College Farm, Kadegaon District Sangli: Maharashtra. *International Journal of Engineering Science and Computing,* November *2017 http://ijesc.org/. pp 15426-15430.*

Quansah, G. W. (2010). Effect of Organic and Organic Fertilizers and their combinations on the Growth and Yield of Maize in the Semi-deciduous Forest Zone of Ghana. M.Sc Thesis submitted to the department of Crop and Soil Sciences, College of Agriculture and Natural Resources, Kwame Nkrumah University of Science and Technology, Kumasi, Ghaja.

Rao, D.V.K.N. and Jose, A.I. (2003). Fertility capability classification of some soils under rubber in Kerala. *Journal of the Indian Society of Soil Science* 51,183-188.

Reichert, J.M, Luis, E.A., Sanches, S, Dalvan, J R., Rainer, H. and Inge, H. (2009). Reference bulk densityand critical degree of compactness for no-till crop production in subtropical highly weathered soils. *Soil and Tillage Research.* Vol 102 pp 242-254

Sadiq A.A and Shuwa S.A (2019). An appraisal of substantive soil and water conservation techniques adopted on different farm locations in Yola South LGA, Adamawa State, Nigeria. *International Journal of Scientific Research Engineering & Technology (IJSRET), ISSN 2278 – 0882 (8):3:164-173.*

Sadiq, A.A., Abdullahi, M., and Ardo. A.U. (2019). An overview of soil fertility degradation in Mubi area, North- eastern part of Nigeria. *International Journal of Scientific and Research Publications, vol. 9 (2) Feb. 2019. 692-697. ISSN 2250-3153.* http://dx.doi.org/10.29322/IJSRP.9.02.2019.p8685

Sadiq, A.A. and Tekwa, I.J. (2022).*Soil Fertility and Management Practices in Mubi Region.* Published by Abti Printing Press, Yola. ISBN. 978-978-959-589-1. Sponssored by Tetfund.

Sadiq, A.A and Vahyala I.E (2023). *Characterization of physical and hydraulic properties of some selected arable lands in Yola South Local Government Area, Adamawa state.* Published by Ahmadu Bello University, Zaria Printing Press. ISBN:978-978-792-494-5. Pp.18-20

Sanchez, P.A. and R.R.B. Leakey, (1997). Land-use transformation in Africa: Three determinants for balancing food security with natural resource utilization. *European Journal of Agronomy.* 7: 15-23.

Sanchez, P.A., Palm, C.A. and Buol, S.W. (2003). Fertility capability soil classification: a tool to help assess soil quality in the tropics. *Geoderma* 114, 157-185.

Singh, B., Chanasyk, D. S., McGill, W. B., and Nyborgo, M. P. K. (1994). Residue and tillage management effects on soil properties ofa Typic Cryoboroll under continuous barley. *Soil Tillage Res. 32: 1 17-133.*

Suharta, N. (2010). Characteristics and problems of marginal soil from acid sedimentary rocks in Kalimantan. *Journal of Agricultural Research and Development. 29 (4), 139-146*