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Evaluation and Classification of Soil Fertility Potentials of Gombi Area of Adamawa State, North-eastern Nigeria

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ABSTRACT

A study was conducted to evaluate the soil fertility potential of Gombi area of Adamawa State, Nigeria. A total of eighty (80) soil samples composite from 0-20 and 20-50cm depths were collected from selected representative locations from the ten (10) wards of the study area and analyzed using standard laboratory procedures. Results obtained revealed that the texture of the soil ranged from sandy loam to sandy clay across the study area. Soil pH was slightly acidic ranged from 6.49 to 6.92. Similarly, there no significant differences in total nitrogen and organic carbon contents among both locations and sampling depths. However, total nitrogen and organic carbon contents were generally low and ranged from 6.7 to 10.3 g kg-1 for organic carbon and 0.88 to 1.0 g kg-1 for total nitrogen across the locations. Similarly, available phosphorus contents were generally low and were linked to P fixation by Fe and Aluminium under the acidic pH range. Three soil FCC classes were identified; SLdek, Ldek, and LSdek with SLdek dominating in six out of ten areas. Sandy nature of the soils, low nutrient reserve, and cation exchange reactions are the dominant constraints in the soils of the area. Integrated soil fertility management which recognizes the use of local inputs such as organic materials available within the environment and appropriate synthetic fertilizer practices could be employed to improve the soil constraints to maintain and sustain the productivity of the soils.

Introduction

The ability of soil to supply the required quantity of plant nutrients is affected by the soil composition, the degree to which the parent materials have been altered by weathering, and the management of the soil by man. Sustainable agricultural production in most tropical countries is under threat due to declining soil fertility and loss of topsoil through erosion (Sanchez, 2002). Soil fertility is associated with the ability of soil to supply the essential nutrient element needed by plants for proper growth and development in the right form and quantity (Brady and Weil, 2008); (Halvin et al., 2005). The fertility status of most soils in Adamawa range from low to moderate. The poor fertility status is attributed to the dominance of low activity clays as well as low organic matter, among others (Hassan et al., 2013; Saddiq et al., 2016). These and other environmental factors result in low soil productivity. The low nutrient holding potentials of the clay minerals also make the soil very vulnerable to nutrient imbalances and acidification, which in turn climax to the problem of aluminum toxicity (Gillman, 1985). Also, the sandy nature of most soils in the tropics is responsible for the rapid water infiltration, poor water holding capacity with little capillary movement, low retention of nutrients.

Soil fertility survey is an essential practice for making any meaningful soil fertility classification and designing an appropriate soil management system. It is vital to understanding the potentials and limitations of soils as well as assigning compatible land-use practices. Soil fertility survey data is an indispensable tool for interpreting soil fertility status and various soil phenomena. The significant decline in soil fertility particularly in smallholder farmers is one of the fundamental causes of declined per capita food production in sub-Saharan Africa and Nigeria in particular (Bationo et al., 1997). Gombi Local Government Area is located in the sub-Saharan region where low soil fertility status especially of N and P has been recognized as one of the significant constraints affecting food production. Also, soil fertility gets depleted as a result of crop-harvest removals, leaching, and soil erosion, and most farmers cannot sufficiently compensate these losses (Shephered and Soule, 1998) Apart from these, the proportion of nutrients lost is greater in sandy soils which are dominant in the study area, hence, this study was carried out to evaluate and classify the fertility potential of soils of Gombi Local Government Area.

2.0. Materials and Methods.

The study was conducted in Gombi Local Government located on longitudes 12° 20' E -12° 50' E and Latitudes 10° 00' 0N, 10° 50'N with an average mean elevation of 530 m above sea level in the northern Guanine savanna agro-ecological zone. The perimeter is 193.3 km with a total area of 184, 200 square hectares. The temperature characteristics are typical of the West African Savanna climate; it is high throughout the year because of the high radiation, which is relatively distributed throughout the year. The temperature ranged from 15.2 to 39 ℃ (Adebayo and Nwagboso, 1999)

Ten (10) villages were selected (Boga, Botala, Dimaska, Girgilann, Gombi, Gurki, Hontumda, Jangala, Kwanta, and Njuda) in Gombi Local Government Area as shown in Figure 1 and 2, and in each, eight (8) surface and subsurface samples were collected from 0-20 and 20-50 cm depth respectively, making a total of eighty representatives composite soil samples for each depth. The collected soil samples were labeled correctly, prepared, and stored for the laboratory analyses.

2.1. Laboratory analysis

The soil texture was determined using the Bouyocus Hydrometer method, as described by Jaiswal (2003). The soil moisture content was determined using the gravimetric method as described by Jaiswal (2003). Particle density and bulk density were determined as described by Jaiswal (2003). Soil colour was determined using Munsell Soil Color Chart. The soil pH was measured in a 1:2.5 soil to water ratio using a glass electrode (H19017 microprocessor) pH meter as described by Jaiswal (2003). The EC was measured using the Jenway 4320 EC meter. The organic carbon content of the soil was determined by the wet oxidation method of Walkley and Black (1934) as described by Jaiswal (2003). Total nitrogen was determined by the macro Kjeldahl digestion, distillation, and titration method. The available P was determined using Bray 1 method as described by Bray and Kurtz (1945) and updated by Jaiswal (2003). The exchangeable bases were extracted with one normal (1N) ammonium acetate, Potassium, and Sodium were determined using a flame photometer, while Calcium and Magnesium were determined by titration with 0.01N EDTA (ethylene diamine tetra-acetic acid) as described by Jaiswal (2003). The soil was extracted with unbuffered 1.0M KCl, and the sum of Al and H was titrated with 0.1M NaOH in the presence of phenolphthalein indicator to a permanent pink color (Jaiswal, 2003). The ECEC was determined by (summation method) summing up the exchangeable bases and exchangeable acidity (Juo, 1978). The percentage base saturation was calculated by dividing the exchangeable bases by the effective cation exchange capacity and expressing the result as a percentage as described by Jaiswal (2003).

$$PBS = \qquad X\,100$$

Sodium absorption ratio (SAR) was determined by estimation as described by Richard (1954)

$$SAR = Na^{2+} / \sqrt{Ca^{2+} + Mg^{2+}}$$

Exchangeable Sodium Percentage (ESP) was estimated based on the below equation as described by Richard (1954).

$$ESP = \frac{Ca^{2+}+Mg^{2+}+K+Na^{2+}}{ECEC} \text{ (Richard 1954).}$$

$$\frac{100(-.0126+.01475SAR)}{1+(-.0126\_.0147SAR)}$$

2.2. Data Analysis

Data obtained were subjected to analysis of variance (ANOVA) to test for the differences between means using the statistical analysis system (SAS) version 9.0. Duncan multiple range tests (DMRT) was used to separate means that were significantly different.

3.0. Result and discussion.

3.1. Soil Physical properties

The effects of soil physical properties are presented in Table 1. Although no significant differences ($P < 0.05$) were observed in percentage sand, silt, and clay concerning sampling depths, significant ($P<0.05$) differences were observed across the locations (Table 1). The highest percentage sand content of 80.60 % was observed at Jangala and was not significantly different from 80.25, 75.93, 75.92, 73.45, 72.88, and 70.75 % recorded at Hurtunda, Botala, Dimaska, Njuda, Gurki, and Gombi respectively. This high sand content may be influenced by the nature and extent of weathering of parent material as well as the eluviation of silt and clay. This is conformity with the findings of Kwparmwang (1993) who reported that tropical soils had undergone intense weathering. Particle size analysis revealed that soils of the study area are predominately sandy loam, loamy sand, and loamy. This is in line with the findings of Sonneveld (2005) who reported that savanna soils are predominantly sandy and attributed it to the nature of the parent materials.

Bulk density, particle density, and porosity were not significantly different across both sampling depths and locations (Table 1). However, bulk density values ranged from 1.43 to 1.56 Mgm-3in Boga and Kwanta respectively, and fall with the optimum range for crop production. This may be associated with similar vegetation cover as well as cultural practices being adopted by farmers across the locations. USDA (1998) reported that Bulk density could be

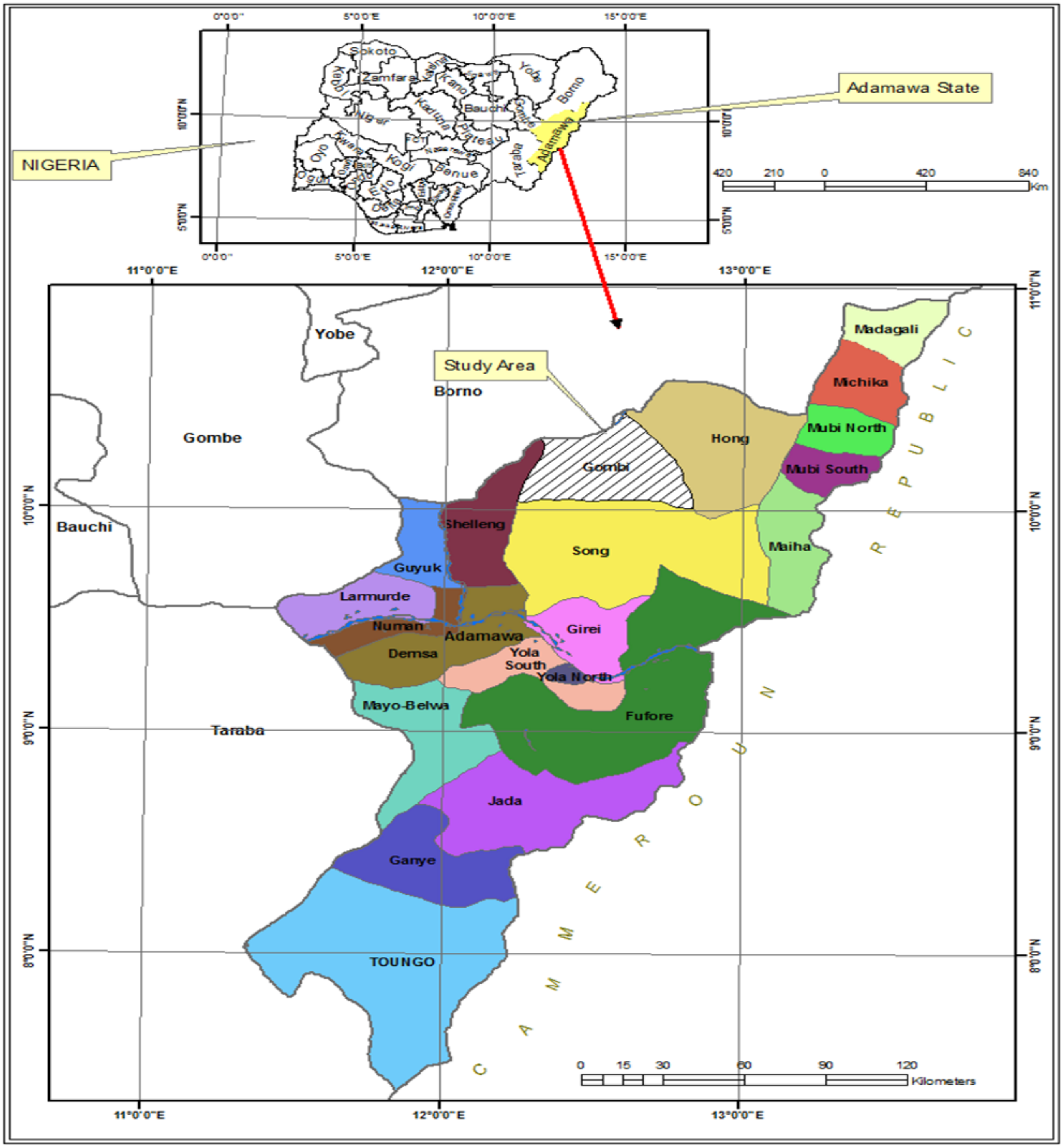

Figure 1: Map of Adamawa State showing Gombi Local Government Area

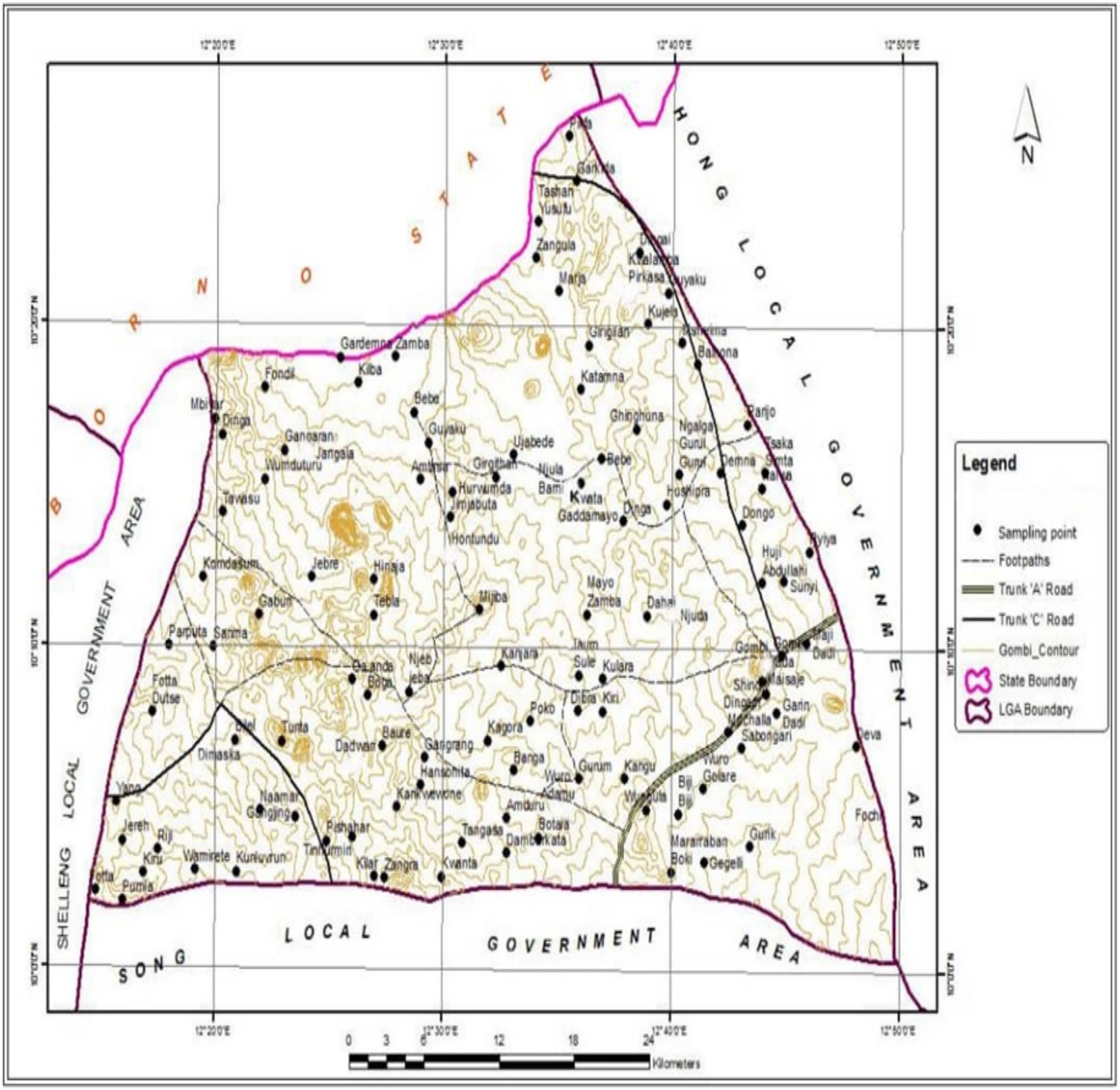

Figure 2: Map Gombi Local Government showing the sampling points

influenced by management practices that affect soil cover, organic matter, soil structure, compaction, and porosity.

3.3. Soil Chemical Properties

The results of soil chemical properties are presented in Table 2. Data obtained revealed that there were no significant differences in soil pH across the depths and sampling locations. Soil pH ranged from 6.49 to 6.92 (Table 2), and fall under the slightly acidic pH range based on the classification of Black (1965). This may not be unconnected to the dominance of sand in the soil separate which predisposes it to leaching. Shehu et al. (2015) in a study of soil fertility status in some selected Sudan Savanna soils of Northern Nigeria reported that savanna soils are mostly slightly acidic and linked it to the sandy nature coupled with the leaching of basic cation which exposes the soils to the dominance of Al3+ and H+ ions, thus acidifying the soils. A higher pH value recorded at Kwanta may be as a result of high soil ECEC recorded at Kwanta compared to the other pedons. Sullivan et al. (2006); Krishnaswamy and Richter (2002) reported higher CEC values for soils having alkaline pH and attributed it to the loss of a proton from carboxyl and hydroxyl groups present in organic matter that significantly add to the greater number of available negative charges in soils at higher pH value.

Table 1: Effect of Sampling Depth and Location on Soil Physical Properties

Location	**Sand**	**Silt**	**Clay**	**Textural class**	**Bulk density**	**Particle density**	**Porosity**
	(%)				(Mgm^{-3})		(%)
Depth							
0-20	73.44a	9.74a	16.83a	SL	1.52a	2.58a	41.01a
20-50	72.93a	9.92a	17.15a	SL	1.50a	2.59a	42.19a
S.E ± (0.05)	6.592	6.090	7.322		0.052	0.066	2.404
Location							
Botala	75.93ab	15.25ab	8.83bc	SL	1.52a	2.58a	40.76ab
Boga	66.17b	22.56a	11.27ab	L	1.43a	2.54a	43.81a
Dimaska	75.92ab	15.13ab	8.95ab	SL	1.53a	2.58a	40.61ab
Girgilann	68.78b	18.94ab	12.29a	SL	1.45a	2.56a	43.20a
Gombi	70.75ab	18.00ab	11.25ab	SL	1.53a	2.59a	41.02ab
Gurki	72.88ab	16.63ab	10.94ab	SL	1.52a	2.65a	42.29ab
Jangala	80.60a	11.94b	7.46c	LS	1.51a	2.58a	41.53ab
Kwanta	67.10b	22.31a	10.58c	L	1.56a	2.58a	39.65b
Njuda	73.45ab	17.30ab	9.25abc	SL	1.50a	2.58a	41.92ab
Hurtunda	80.25a	11.45b	8.30bc	LS	1.52a	2.58a	41.24ab
S.E ± (0.05)	3.301	2.472	0.941		0.033	0.034	1.203

Means with the same letters on the same column are not significantly different at P = 0.05, BD=Bulk density, PD=Particle density, SL= sandy loam, L=Loam, Loamy sand

Low Electrical Conductivity (EC) was observed across the locations and ranges from 0.14 dS m-1 in Njuda to 0.26 dSm-1 each at Boga and Jangala (Table 2). Brady and Weil (2008) reported a critical EC value of 4 dS m-1. The low EC observed may be linked to high leaching of salts to a much lower horizon due to the sandy nature of the soils. Similar results were reported by Musa (2015) when evaluating the fertility potential of Loko, Adamawa State.

No significant differences were observed on Organic carbon and total nitrogen contents across both sampling depths and locations. Similarly, values were generally low and ranged from 6.7 to 10.3 g kg-1 for organic carbon while that of total N ranges from 0.88 to 1.0 gkg-1. These low values may be linked to the rapid decomposition of organic matter observed in the study area due to high temperature. It may also be attributed to crop residue removal. Raji and Mohammed (2000) reported that more than 80 % of Nigerian savanna soils are low in organic carbon. However, available phosphorus contents ranged from 6.61 mg kg-1 in Botala to 7.30 mgkg-1 in Njuda and fall between the low to moderate class. Lower values of available P may be attributed to continuous use of N base fertilizer which decreases the soil pH to slightly acidic, thereby encouraging P fixation by iron and Aluminium. Brady and Weil (2008); Hamdi et al. (2013) explained that a decrease in soil pH is the major factor responsible for low available P and linked it to P fixation by Fe and Al oxides and hydroxides at such low pH values. A similar finding was reported by Idigbor et al. (2008) and attributed it to the high phosphorus fixation capacity of most tropical savanna soils.

There were no significant differences in Effective Cation Exchange Capacity (ECEC) on with depth. Interestingly, significant differences ($P < 0.05$) were observed across the locations (Table 2). Highest ECEC values of 9.81 cmol(+) kg-1 at Hurtunda and was not significantly from 9.72, 9.51, 9.33, 9.26, and 9.09cmol(+)kg-1 recorded at Njuda, Gurki, Girgila, and Gombi respectively. However, it was significantly ($P<0.05$) different from the rest of the treatments. These differences may not be unconnected to variation in clay and organic matter contents across the locations. Peinemann et al. (2000), Parfit et al. (1995) obtained significantly higher CEC in the presence of organic matter and linked it to an increase in negative charges arising from the carboxylic group. However, ECEC values were generally low across the study area (Table 2). The low ECEC values may be linked to low organic matter and clay content in the soils of the study area and similarities of parent material from which the soils were formed (Brady and Weil, 2008). Esu (2005) reported similar low ECEC values in selected soils of Sudan Savanna Biomass of Northern, Nigeria.

There were no significant differences in Sodium Adsorption Ratio (SAR) across both sampling depths and locations (Table 2). Similarly, Low Sodium Adsorption Ratio (SAR) of the study area may be attributed to the low concentration of soluble salt (sodium) adsorbed onto the soil cation sites due to high leaching of soluble salt from the soil surface. Similar values were reported by Kings et al. (1990) who observed, low SAR when natural precipitation moved Na through the profile, decreasing the rate of accumulation in the soil profile.

Similar to what was obtained for SAR, there were no significant differences in Exchangeable sodium percentage (ESP) across both sampling depths and locations. The ESP which identified the degree to which the exchange complex is saturated with Na was very low and ranged from 2.51 to 5.28 % (Table 2). The low ESP observed across the locations may be as a result of low sodium accumulation, rainfall patterns, and the acidic conditions of the soils. It may also be due to the sandy nature of the soils which encourages significant leaching of soluble salts from the soil profile. As the rainwater percolates, it dissolves and washes down Na cations which may accumulate in groundwater. This concurs with the report of Dupriez and Deleamer (1989) who opined that leaching is a significant way of reclaiming sodic soils.

3.4. Soil fertility status of the Area

Based on the soil taxonomy, the soils evaluated on physical and chemical properties are generally of low fertility status. However, using a more relevant technical classification system; the fertility capability classification (FCC) of Sanchez et al. (2003), the soils of the area could further be differentiated for management purposes and fertilizer recommendations. FCC has proved very useful for both pedologists and agronomist, especially in tropical soils (Sanchez et al., 1982; Sanchez et al., 2003). Using the FCC system (Table 3), the soils of the local government can be classified into three; SLdek, LSdek, and Ldek. Botala, Dimaska, Girgila, Gombi, Gurki, Jargala, and Kwanta have sandy (S) topsoil, loamy (L) subsoil, dry ustic moisture regime (d) (dry>60 consecutive days/year, low ECEC (e) and low nutrient reserve (siliceous). Njuda and Hurtunda areas are loamy at the topsoil (L), sandy at the subsoil (S), dry ustic moisture regime (d), low ECEC (e) with low nutrient reserve capital (k). Boga area has loam soil at the topsoil (L), dry ustic moisture regime, and low nutrient capital reserve (k). Thus, all three identified FCC classes: SLdek, LSdek, and Ldek have high soil fertility constraints. However, SLdek is further constrained due to its high risk of erosion. Sanchez et al. (2003) indicated that soils with sandy topsoil and loam subsoil are highly susceptible to erosion risk.

4.0. Conclusion

The soils of Gombi LGA, Adamawa State, are dominantly sandy in texture, soil pH was slightly acidic while organic carbon, total nitrogen, available phosphorus, and effective cation exchange capacity were low. Similarly, OC, TN, AVP, exchangeable K, ECEC, and BS were all low both at the surface and sub-surface samples. The soils are thus of low fertility status.

Three soil FCC classes were identified; SLdek, Ldek, and LSdek with SLdek dominating in six out of ten areas with pronounced soil fertility constraint resulting from declined organic matter level all occurring on fairly and gently undulating terrain (*)(0-2). Sandy nature of the soils and low nutrient reserve and cation exchange reactions are dominant constraints in the soils of the area. Integrated soil fertility management which recognizes the use of local inputs as organic materials available within the environment and appropriate synthetic fertilizer practices could be employed to ameliorate all the soil constraints to maintain and sustain the productivity of the soils.

Table 2: Effect of Sampling Depth and Location on Some Soil Chemical Properties

Treatments	pH in H_2O	EC (dSm^{-1})	OC	TN	AVP ($mgkg^{-1}$)	Ca	Mg	Na	K	TEB	TEA	ECEC	BS	SAR	ESP
			(gkg^{-1})			Cmol(+)kg^{-1}							(%)		(%)
Depth															
0-20	6.75a	0.21a	9.80a	0.98a	6.77a	4.225a	1.518a	0.359a	1.719a	7.821a	1.23a	9.046a	60.52 a	0.216a	3.97a
20-50	6.81a	0.19a	9.11b	0.91a	6.956a	4.112a	1.515a	0.343a	1.718a	7.688a	1.28a	8.968a	59.47a	0.202a	3.82a
S.E ± (0.05)	0.1205	0.0458	0.0239	0.029 1	0.7462	0.7617	0.3007	0.0724	0.2854	0.334	0.183	0.2439	8.1524	0.0418	0.553
Location															
Botala	6.87a	0.24a	8.7a	0.88a	6.61a	3.80ab	1.36ab	0.26a	1.72bc	7.14c	1.23a	8.37b	63.05ab	0.16a	3.11a
Boga	6.88a	0.26a	9.2a	0.92a	6.83a	4.70a	1.57ab	0.39a	1.39c	8.05ab	1.28a	9.33a	50.15c	0.23a	4.18a
Dimaska	6.81a	0.21ab	9.9a	1.00a	7.23a	4.69a	1.73ab	0.39a	0.33d	7.14c	1.25a	8.39b	36.62d	0.22a	4.65a
Gurgila	6.65a	0.17ab	9.3a	0.94a	7.11a	4.03ab	1.63ab	0.47a	1.93b	8.06ab	1.20a	9.26ab	65.72ab	0.28a	5.08a
Gombi	6.83a	0.19ab	8.7a	0.88a	7.00a	4.06ab	1.28b	0.48a	2.09ab	7.91ab	1.18a	9.09ab	67.98ab	0.29a	5.28a
Gurki	6.92a	0.20ab	9.3a	0.93a	7.25a	4.24ab	1.54ab	0.29a	2.34a	8.41a	1.10a	9.51a	70.83a	0.18a	3.05a
Jangala	6.75a	0.26ab	9.7a	0.97a	5.72a	3.10b	1.40ab	0.26a	1.99b	6.75c	1.50a	8.25b	59.52abc	0.17a	3.15a
Kwanta	6.49a	0.17ab	10.3a	1.03a	6.74a	4.05ab	1.24b	0.21a	1.59c	7.09c	1.27a	8.36b	58.84bc	0.13a	2.51a
Njuda	6.77a	0.14b	9.7a	0.97a	7.30a	4.61a	1.49ab	0.33a	1.89b	8.32a	1.40a	9.72a	61.31ab	0.19a	3.40a
Hurtunda	6.83a	0.17ab	9.6a	0.96a	6.84a	4.41a	1.93a	0.42a	1.9b	8.68a	1.13a	9.81a	65.96ab	0.25a	4.28a
S.E ± (0.05)	0.14	0.03	0.06	0.06	1.27	0.90	0.37	0.17	0.28	0.37	0.25	0.44	7.01	0.09	3.31a

Means with the same letters on the same column are not significantly different at P = 0.05

Table 3: Fertility Classification of Gombi Area

Area	Unit	Description
Botala	SLdek	Sandy loam soil, formed under dry ustic soil moisture regime, low in ECEC (e) with pronounced soil fertility constraint.
Boga	Ldek	Loam soil, formed under a dry ustic regime, low in ECEC (e) and a low values of exchangeable K, with a potential soil fertility constraint
Dimaska	SLdek	Sandy loam soil, formed under dry ustic soil moisture regime low in ECEC (e) and with pronounced soil fertility constraint.
Girgilan	SLdek	Sandy loam soil, formed under dry ustic soil moisture regime low in ECEC (e) and with pronounced soil fertility constraint occurring.
Gombi	SLdek	Sandy loam soil, formed under dry ustic soil moisture regime low in ECEC (e) and with pronounced soil fertility constraint.
Gurki	SLdek	Sandy loam soil, formed under dry ustic soil moisture regime low in ECEC (e) and with pronounced soil fertility constraint.
Jangala	SLdek	Sandy loam soil, formed under dry ustic soil moisture regime low in ECEC (e) and with pronounced soil fertility constraint.
Kwanta	SLdek	Sandy loam soil, formed under dry ustic soil moisture regime low in ECEC (e) and with pronounced soil fertility constraint.-----
Njuda	LSdek	Loamy soil, formed under dry ustic soil moisture regime low in ECEC (e) and with pronounced soil fertility constraint
Hurtunda	LSdek	Loam sandy soil, formed under dry ustic soil moisture regime low in ECEC (e) and with pronounced soil fertility constraint.

Appendix I: The Global Positioning System (GPS) Coordinates of the Study Locations in Universal Transverse Mercator (UTM)

Location	Easting (X)	Northings (Y)
Botala	230456	1115120
Boga	230456	1115120
Dimaska	206446	1116751
Girgilann	278441	1125871
Gombi	251817	1123532
Gurki	226117	1140146
Jangala	206063	1132153
Kwanta	225915	1111732
Njuda	211032	1112401
Hurtunda	226123	1128315

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