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Morphological and Physico-Chemical Properties of the Upland Soils of the Three Selected Agricultural Zones of Kebbi State, North Western, Nigeria.

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ABSTRACT

This study was aimed at obtaining information about the morphological, physical and chemical characteristics of the upland soils of the three selected agricultural zones of the State. Three pedons, one from each agricultural zone, were dug and designated as AUL, BUL and YUL in Argungu, Birnin Kebbi and Yauri agricultural zones, respectively. From each horizon of each pedon, morphological features were observed. Soil samples were then taken from each genetic soil horizon for laboratory analysis for physical and chemical characteristics.

Result obtained shows that Pedon AUL and BUL were loamy sand in texture while pedon YUL was sandy loam and that might be the reason why upland rice has been grown on these soils.

Based on the values of exchange bases and CEC obtained for AUL, BUL and YUL, the soil could be said to be medium in fertility and therefore appropriate management practices such as addition of organic matter, crop rotation, fallow periods, application of fertilizer and growing of leguminous crops should be applied on these soils for the sustainable agricultural production. pH of the soils are thus moderately acidic, highly acidic and slightly acidic to neutral as per AUL, BUL and YUL, respectively. Based on the concentration of pH, EC and ESP, the soil could be considered free from salinity and sodacity hazards and therefore good for crop production under appropriate management practices.

INTRODUCTION

As a natural body, a soil is made up of genetic parts called Horizons which lie roughly parallel to the surface and are manifestations of variation in soil properties with depth. The kinds and arrangement of horizons determine the nature of the soil profile. The profile in turn is the basis for recognizing and classifying individual kinds of soil (Hausenbuiller, 1980). Dokuchaev and Sibirtsev, 1993 opined that soil horizons were used solely for descriptive purposes, but they were later identified as genetic layers more or less parallel to the earth's surface that could be (a) distinguished on the basis of morphological, chemical, and physical properties and (b) used to interpret the developmental history of the soil. The soil information obtained from the systematic sampling and analysis of soils from the profile pits is important for the effective planning of different land uses, as they provide information related to potentials and constraints of the soils. The well drained upland soils are usually associated with loose structure, large volume of non-capillary pore space and hence good drainage and aeration. They have low moisture retention capacity, high permeability and low exchangeable capacity (Richard, 1954; Michael, 1978 and Pitty, 1979). All these properties make upland soils low in fertility but less risk of sodicity and salinity hazards. According to Pulakeshi *et al.*, 2014, soils vary both in their physical and chemical properties and hence agricultural production is governed by major soil types and precipitation patterns. In view of all these, it becomes necessary to study the physical and chemical characteristics of profile pits of upland soils of the three agricultural zones of Kebbi State with aim of generating adequate information required for the purpose of determining the potentiality of soils of the State for their agricultural production as well as the appropriate management practices to be applied.

MATERIALS AND METHODS

Kebbi State - Location and Agroclimate

Kebbi State is situated in the extreme north-west of Nigeria between latitudes $10^{o}06^{1}$-$13^{o}10^{1}$ North and longitudes $3^{0}0^{1}$-$6^{0}03^{1}$ East (KARDA, 1998). It shares boarder with both Niger and Benin Republics in the west. On the East, it is bordered by Sokoto State and in the South by Niger State. Kebbi State occupies a land area of 37,698 square kilometers, 36% (13,745.25km^2) of which is an arable land (KICL, 2000). KARDA, 1998 gave a total arable fadama land area in the State as 1303.84 square kilometers. The remaining 12,441.41 km^2 is up land used for arable farming and other purposes.

Vegetation of the Study Area: The natural vegetation in Kebbi State follows the rainfall pattern and other climatic elements. KARDA, 1998 reported that the vegetation of the State is broadly classified as Savanna and can be divided into three categories: Northern Guinea which occupies south- eastern parts of the State, Sudan Savanna which is found in the middle and the Sahel which is found in the extreme northern part of the State where sparse trees and shrubs of different kinds exist.

Soils of the Study Area: According to (KICL, 2000), the State has the following soil types: Sandy soils found in the upland locations of the North, North West and Central parts of the State; Ferruginous tropical soils found in the South – Eastern parts of the State; Lateric soils found all over the state, Black Cotton soil found in the South-Eastern and Southern parts of the State and Hydromorphic soils found in the floodplains of the major rivers and enclosed depressions (Fadama areas).

Land Use in the Study Area: The agricultural land in Kebbi State envisages the production of crops such as millet, sorghum, cowpea, groundnut, cotton, maize and rice during the rainy seasons. For dry season agriculture, crops like rice, onions, tomatoes, wheat, sunflower, garlic and many other vegetables are grown mostly along river valleys of the State. The forest land is suitable for wood and timber as well as other economic trees such as Gum rabic, Sheanut, Cashew, Mangoes, Guava and other tropical fruit trees abound within the State. Floodplains in the State contribute immensely to domestic fish production in Nigeria.

Sampling Sites:- The upland soils in Kebbi State cover some Local Government Areas (LGA) in the three Agricultural Zones of the State; Argungu, Birnin Kebbi and Yauri (Figures 1,2 and 3). One profile pit was excavated from each of the three Agricultural Zones (Argungu, Birnin Kebbi and Yauri). Profile pits dug were designated AUL (Argungu Upland), BUL (Birnin Kebbi Upland) and YUL (Yauri Upland). From each profile pit dug, samples were taken from each identified horizon.

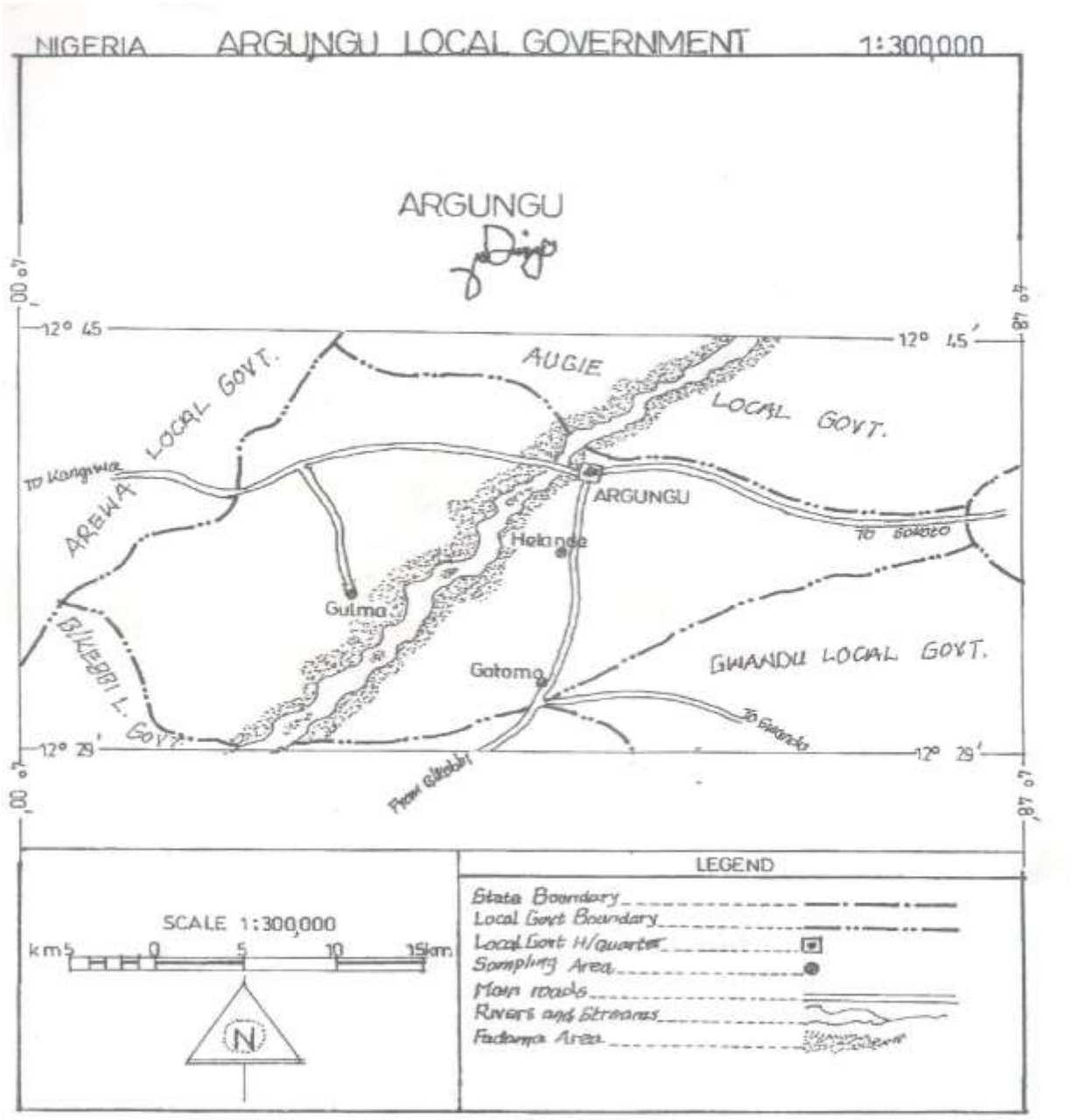

Fig.1 Map of Argungu Local Government Area

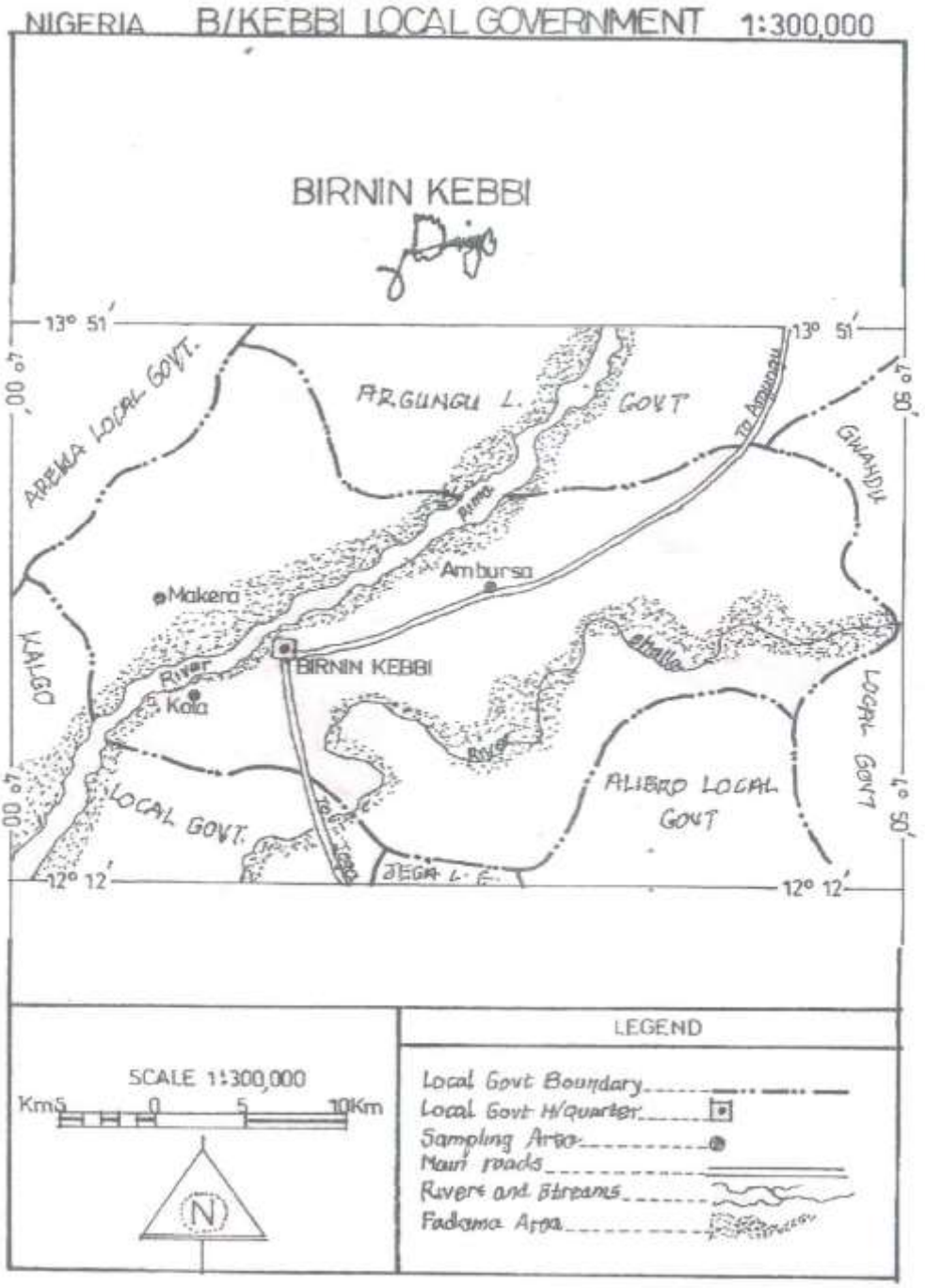

Fig. 2 Map of Birnin Kebbi Local Government Area

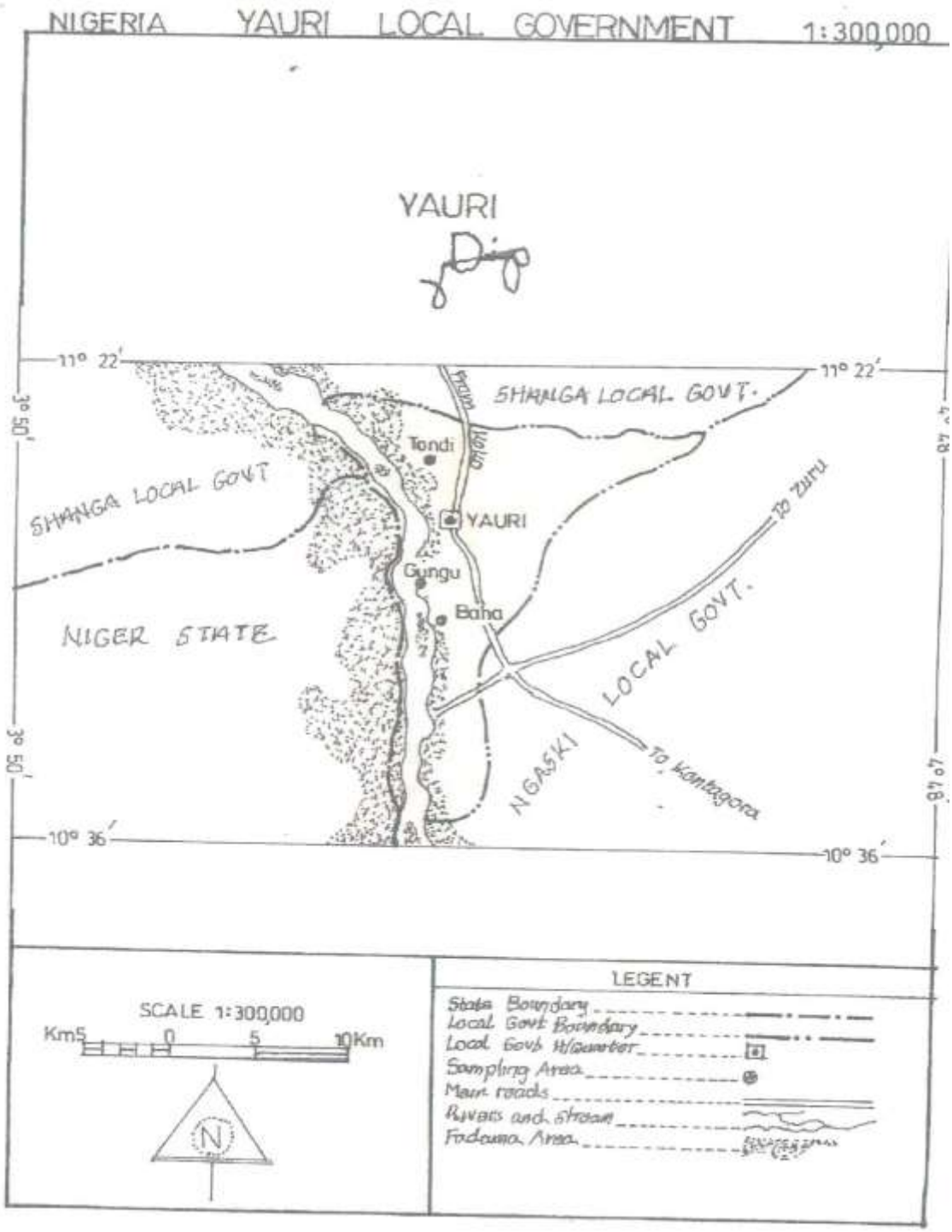

Fig.3 Map of Yauri Local Government Area

Analytical Procedures

The soil profiles were described according to FAO, 2006 manual. The processed soil samples were analyzed for various physical and chemical properties following the procedures as described by (Page *et al.,* 1982). The particle size analysis was carried out by the (Bouyoucos, 1951) hydrometer method as modified by Day, 1965. The texture was determined on the USDA textural triangle. Organic carbon was determined by (Walkley and Black 1934) wet combustion method (CF 1.33). Total nitrogen was determined by macro-Kjeldahl digestion and distillation method. Available phosphorus was obtained by the use of Bray-1 method (0.025 N HCl + 0.03N NH_4F) as described by Bray and Kurz, 1945). Cation exchange capacity was determined by ammonium saturation method as described by

(Chapman, 1965). Potassium (K) and sodium (Na) concentrations in solution were determined by flame photometry (Uriyo and Singh (1974). Calcium (Ca) and magnesium (Mg) were determined by EDTA titration method as described by (Stewart, 1974). The soil pH was determined using pH meter in a 1:2 soil water mixture as recommended by Alberta Saskart Chewan and Mannitaba Provisional Laboratory (ASCMPL, 1988). Electrical conductivity (EC) was also determined in a 1:2 soil water ratio at 25^{o}C on a conductivity meter. The result was multiplied by a conversion factor of 2.063 (ASCMPL, 1988) to obtain the saturation extract. The exchangeable sodium percentage ESP was calculated as follows:-

$$\frac{\text{Exchangeable } Na^{+}}{\text{CEC}} \times \frac{100}{1}$$

Where Na^{+} and CEC were in cmol (+)kg^{-1} of soil. Base saturation was obtained by summation of the values of basic exchangeable cations. Percentage base saturation on the other hand was determined by using the formula below;

$$\frac{\text{Base saturation}}{\text{CEC}} \times \frac{100}{1}$$

Statistical Analyses

The data were subjected to GLM procedure using Statistical Analysis Software (SAS Institute 1999). Means that were statistically different were separated using Duncan's New Multiple Range Test (Duncan, 1955).

RESULTS AND DISCUSSIONS

Table 1: Morphological properties of the soils of Argungu, Birnin Kebbi and Yauri agricultural zones

Pendon Boundary features	Horizon	Depth	Colour* (cm)	Mottling	Textural	Structure* class	Consistence*	Other
AUL								
Ap	0-37	10yRS5/2	LS	Abk	Fr,	mr, mp	C	
AB	37-71	10yR 7/3	LS	Abk	Fr	mr, mp	C	
B	71-122	10yR6/3	LS	Sabk	Fr	mr, fp	C	
C	122-197	10yR5/6	LS	Sabk	Fr	Fr, fp	C	
BUL								
Ap	0-30	10yR63/6	LS	Sabk	Fr,	mr, mp	C	
AB	30-35	10yR 7/4	LS	Sakb	Fr	mr, mp	C	
2B1	35-95	10yR 7/3	LS	Sabk	Fr	mr, mp	DS	
2B2	95-115	10yR7/3	LS	Sabk	Fr	mr, fp	C	
BC	115-175	10yR 8/3	SS	Sabk	Fr,	Fr	C	
C	175-200	10yR8/3	SS	Sabk	Fr	Nr	C	
YUL								
Ap	0-18	10yR6/3	LS	Gn	Vfr,	Fr,fp	C	
B	18-28	10yR7/4	SL	Gn	Vfr	Fr,fp	C	
C	28-70	10yR4/3	SL	Gn	Vfr	Fr fp	C	

*Note: symbols or codes according to FAO, 2006
Structure:- Sabk = subangular blocky, Abk = angular blocky, Consistence: , fr=friable, vfr=very Friable; - Roots: 1= mr= many roots, fr=few roots, nr=no roots,, pores:- mp = many pores, fp=few Pores;Gn= granular, Boundary: ds= diffused, C=clear.

The horizons sequence of the Pedon AUL of the upland soil of Argungu Agricultural Zone were clear and conspicuous in demarcation. The pedon comprised of Ap and AB horizonsS at the depth of 71 - 122 cm. Underlying the B horizon was the C horizon within the depth at the depth of 0 – 37cm and 37 -71 cm, respectively. Below the AB horizon was the B of 122 - 197cm. The color of the top soils (Horizon AP) of Pedon AUL was grenished brown (10YR 5/2). No mottle was observed an indication that the soil was well drained. The color of the AB horizon (37 -71 cm) on the other hand was observed to be very dark brown (10YR 2/3). At the depth of 71 -122 cm (B horizon), the color was pale brown (10YR 6/3) while horizon C (122 -197) was observed to be yellowish brown (10YR 5/6) in color. The texture of the soils of the Ap (0 -37cm); AB (37 - 71cm); as well as B and C horizons (71 – 122 and 122 -197cm), respectively of the Pedon AUL was loamy sand. The structure of the soils of pedon AUL at Ap and AB horizons was angular blocky while that of B and C

horizons was sub angular blocky. All **the** four observed horizons in pedon AUL were friable in consistency.

However, horizons Ap, AB and B of AUL consist of many roots while few roots were observed in C horizon (122 – 197 cm). Many pores were also observed in Ap and AB horizons an indication of active activities of soil microbes. On B and C horizons on the other hand, only few pore spaces were observed, an indication of very few microbial activities in the underlying horizons.

The horizon sequence of the Pedon BUL (upland soils) of Birnin Kebbi Agricultural Zone was clear at Ap horizon (0 - 30cm, but diffused at AB horizon (30 - 35 cm). However, the boundaries for 2B1 (35 - 95cm), 2B2 (95 - 115cm), BC (115 - 175cm) and C (175 - 200cm were very clear in demarcation.

The color of the pedon BUL was almost the same in appearance , except in horizon Ap (0 - 30cm) with pale brown color (10YR 6/3) and 2B1(35-95 cm) which appeared light yellowish brown (10YR 6/4) in color. The rest of the horizons such as AB(30- 35cm), 2B2 (95 - 115cm), BC (115 - 175cm) and C (175 - 200 cm) were all very pale brown in color with color index of 10YR7/4, 10YR7/3, 10YR8/3 and 10YR8/3, respectively. No mottle was observed throughout the pedon an indication that there was very good drainage in the upland soils of the study area.

The color of the pedon BUL was almost the same in appearance , except in horizon Ap (0 - 30cm) with pale brown color (10YR 6/3) and 2B1(35-95 cm) which appeared light yellowish brown (10YR 6/4) in color. The rest of the horizons such as AB(30- 35cm), 2B2 (95 - 115cm), BC (115 - 175cm) and C (175 - 200 cm) were all very pale brown in color with color index of 10YR7/4, 10YR7/3, 10YR8/3 and 10YR8/3, respectively. No mottle was observed throughout the pedon an indication that there was very good drainage in the upland soils of the study area. The horizon sequence of the pedon YUL of the upland soils of Yauri Agricultural Zone comprised distinct horizons. The Ap horizon (0 - 18cm), B horizon (18 - 28cm) and the underlying C horizon (28 - 70cm) at which the impermeable layer was reached. The boundaries of all the three layers were clear in demarcations.

Table 2: Textural Class Distributions of the soils of different horizons in pedons of Argungu, Birnin Kebbi and Yauri Agricultural Zones

Pedon	Horizon	Depth (cm)	Sand	Silt	Clay	Textural Class
AUL	Ap	0-37	84.3	5.9^{b}	9.8^{a}	LS
	AB	37-71	84.3	9.8^{a}	5.9^{a}	LS
	B	71-122	84.3	9.8^{a}	5.9^{a}	LS
	C	122-127	84.3	9.8^{a}	5.9^{a}	LS
		Means	84.3	8.8	6.9	LS
BUL	AP	0-30	88.2^{b}	9.8^{a}	2.0	LS
	AB	30-35	88.2^{b}	9.8^{a}	2.0	LS
	2B1	35-75	88.2^{b}	9.8^{a}	2.0	LS
	2B2	75-115	88.2^{b}	9.8^{a}	2.0	LS
	BC	115-175	90.2^{a}	7.8^{b}	2.0	LS
	C	175-200	90.2^{a}	7.8^{b}	2.0	LS
		Means	88.9	9.1	2.0	LS
YUL	Ap	0-18	49.0^{c}	37.3^{a}	13.7^{a}	LS
	B	18-28	52.9^{ab}	35.5^{b}	11.8^{2}	LS
	C	28-70	54.9^{a}	33.3^{b}	11.8^{d}	`LS
		Means	52.2	35.4	12.4	LS

LS=Laamy sand, SL=Sandy loam, SS=sandl

Means bearing difference letters along the same column differed significantly (P<0.05)

The result of the particle size distribution of the upland soils is shown in Table 2. The result showed that with the exception of Pedon YUL of the upland soils of Yauri Agricultural Zone with sandy loam texture, all the remaining two profiles (Pedons AUL and BUL) of the upland soils of Argungu and Birnin Kebbi Agricultural Zones were loamy sand in texture with mean values of 84.3% sand, 8.8% silt and 6.9% clay for AAZ and 88.9% sand, 9.1% silt and 2.0% clay for BAZ. The texture of the soil (loamy sand) in these Agricultural Zones agreed with report that the surface texture for the upland soils are fine sand changing in some cases to loamy sand. However, the upland soils of Yauri Agricultural zones were observed to contain high percent of silt and clay, a condition conducive for the cultivation of upland rice (Olaleye, 1998). This might be the reason why upland rice is produced in large quantities on the upland soils of this area.

Table 3: Chemical Characteristics of the Soils of Different Horizons in Pedons of Argungu, Birnin Kebbi and Yauri Agricultural Zones

			Exchangeable bases									
Pedon	Horizon	Depth (cm)	Ca^{2+}	Mg^{2+}	Na^{+}	$K2^{+}$	CEC	BS	PBS,%	ESP.%	pH	EC
(dSm^{-1})				Cmolkg^{-1}								
AUL												
Ap	0-37	1.25	1.45	0.65	0.49	5.18	3.8	74	9	5.5	0.2	
AB	37-71	1.25	0.35	0.83	0.51	5.32	2.9	55	16	5.4	0.2	
B	71-122	1.25	0.35	0.78	0.51	5.36	2.9	54	15	5.5	0.2	
C	122-197	1.25	0.40	0.61	0.36	5.42	2.6	48	11	5.6	0.2	
	Means	**1.25**	**0.63**	**0.71**	**0.53**	**5.32**	**3.1**	**58**	**13**	**5.5**	**0.2**	
BUL												
Ap	0-30	1.25	1.25	0.52	0.36	5.38	3.38	52	9	5.2	0.4	
AB	30-35	1.25	1.25	0.52	0.36	5.38	3.38	68	9	4.8	0.4	
2B1	35-95	1.25	1.25	0.52	0.36	5.34	3.38	63	9	4.7	0.2	
2B2	95-115	1.20	1.25	0.61	0.38	5.18	3.44	66	11	4.5	0.2	
BC	115-175	1.20	1.20	0.61	0.41	4.98	3.42	68	12	4.5	0.2	
C	175-200	1.15	1.25	0.61	0.38	4.94	3.39	68	12	4.5	0.2	
	Means	**1.21**	**1.25**	**0.56**	**0.37**	**5.2**	**3.39**	**63**	**10**	**4.87**	**0.2**	
YUL												
Ap	0-18	1.35	1.40	0.80	0.36	5.88	3.9	6.6	14	5.2	0.4	
B	18-28	1.35	1.30	0.70	0.26	5.52	3.6	6.5	12	5.4	0.6	
C	28-70	1.30	1.35	0.70	0.28	5.46	3.6	6.6	13	5.4	0.6	
	Means	**1.00**	**1.35**	**0.74**	**0.30**	**5.60**	**3.7**	**6.5**	**13**	**5.3**	**0.5**	

Results of the chemical properties of the different agricultural zones were presented in Table 3. The results showed that Ca^{2+} and Mg^{2+} ions were the predominant cations in upland soils of AAZ, BAZ and YAZ. The upland soils of AAZ, BAZ and YAZ were observed to contain Ca^{2+} values of 1.25, 1.21 and 1.0 cmol (+)kg^{-1} , respectively. The mean Mg values were 0.63, 1.25 and 1.35 cmol (+)kg^{-1} for AAZ, BAZ and YAZ, respectively. The values were lower than the obtained values of the flood plain soils of the study area. The reason being predominant sandy nature of the soils in which leaching of available bases was prominent. Exchangeable potassium and sodium were generally low compared to calcium and magnesium in the uplands soils of all the three agricultural zones studied. For AAZ, the values for K ranged from 0.36 - 0.51cmol(+)kg^{-1} (mean 0.53 cmol(+)kg^{-1}) and that of Na 0.61 - 0.83cmol(+)kg^{-1} (mean 0.71cmol(+)kg^{-1}), for BAZ, the values for K ranged from 0.36- 0.49cmol(+)kg^{-1} (mean 0.53 cmol(+)kg^{-1}) and that of Na ranged from 0.61 - 0.83cmol(+)kg^{-1} (mean 0.71), while K values for the upland soils of YAZ ranged from 0.26 - 0.36cmol(+)kg^{-1} (0.30 cmol(+)kg^{-1}) and Na values of 0.70 - 0.83cmol(+)kg^{-1} (mean, 0.74 cmol(+)kg^{-1}) (Table 3).

The CEC ranges for the upland soils of AAZ, BAZ and YAZ (pedons AUL, BUL and YUL) were 5.18 - 5.42 (mean, 5.32 cmol (+)kg^{-1}), 4.94 - 5.38 (5.2 cmol(+)kg^{-1}) and 5.46 - 5.88 (mean 5.6 cml(+)kg^{-1}), respectively (Table 3). The CEC values for soils of pedons AUL and YUL increased progressively with increasing depth while those for soils in pedon BLL decreased with increasing depth (Table 3). The CEC values of the upland soils of all the three agricultural Zones were low based on the standard ratings (Esu, 1991). The reported low CEC values of the upland soils of the study area might be attributed to the slightly acidic nature of these soils. According to Yagodin (1984), the lower the concentration of H^{+} ions in the soil solution the higher the exchange capacity. High concentration of the sand particles could also be another contributing factor as the exchange capacity of the soils of heavy texture with high content of fine particles (clayey and loamy) have an exchange capacity greater than that of light sandy soils (Yagodin, 1984).

The pH ranges for the upland soils on the other hand were 5.4 - 5.6 (mean5.5), 4.5- 5.2 (mean 4.7) and 6.5 - 6.7 mean (6.6) for AAZ, BAZ and YAZ (Pedons AUL, BUL and YUL), respectively (Table 3). The pH of soil of pedon YUL was slightly acidic to neutral, a condition favorable for the growth of many crops and soil micro- organisms. The pH was observed to increase and decrease irregularly with increasing depth in all the

profiles except in pedon BUL where pH decreases progressively with increasing depth. Similar trends were observed and reported by (Yakubu and Ojanuga, 2011). The low pH in pedons AUL and BUL) indicated that these soils have been subjected to a longer period of leaching (Yakubu, 2006). According to Esu (1991), soils derived from highly siliceous sand stone are acidic.

The mean EC values of the upland soils of AAZ, BAZ and YAZ on the other hand were 0.2 dSm^{-1}, 0.2dSm^{-1} and 0.5dSm^{-1}, respectively (Table 3). With the exception of pedon AUL of the upland soils of AAZ with uniform EC values, the remaining pedons (BUL and YUL) had irregular distribution with increasing depth.

The ESP values for upland soils (pedons AUL, BUL and YUL) ranged from 11 - 16 (mean 13 %), 9 - 12 (mean 10) and 12 - 14 (13%), for AAZ, BAZ and YAZ, respectively.

The higher ESP values in the upland soils were observed in pedons AUL and YUL with mean ESP value of 13% each. Such higher ESP value could be attributed to the nature of the parent materials from which these soils were derived

CONCLUTION

The studied pedons showed varying morphological, physical and chemical properties and could therefore likely behave differently in terms of their use and management. Pedon AUL was observed to be loamy sand. Horizons Ap, and AB were angular blocky while 2Bw1 and 2Bw2 were sub angular blocky in structure. All the horizons of pedon AUL were friable with clear boundaries. The AP and AB have many roots and pores an indication of microbial activities in the soil. Pedon BUL was sub angular blocky in structure and with exception of AB horizon, all the remaining horizons were clear in boundaries. Horizons AB to 2B2 were loamy sand while 2Bt1 and 2Bt2 were light sandy loam in texture. The horizons of pedon YUL were angular in structure and clear in boundaries. Ap was Loamy sand and AB and B were sandy loam in texture. The solis were very friable with few pore spaces an indication of poor drainage.

The results of the particle size distributions of upland soils of AUL and BUL were loamy sand with mean values of 84.3% sand, 8.8% silt, and 6.9% clay for AAZ and 88.9%sand, 9.1% silt, and 2.0% clay for BAZ. YAZ was observed to be sandy loam with mean values of 52.2% sand, 35.4% silt and 12.4% clay.

The BUL and YUL contained Ca values of 1.25, 1.21 and 1.0 cmolkg-1 respectively. The exchangeable K ranges from 0. 36 -0.51 (mean, 0.53 cmolkg-1), 0.36-0.49 (mean, 0.53 cmolkg-1), and 0.26 – 0.36(mean, 0.30 cmolkg-1) for the AUL, BUL and YUL, respectively. The Na ion ranged from 0.61 0.83 (0.71cmolkg-1), 0.61-0.83 (mean, 0.71cmolkg-1) and 0.70-0.83 (mean, 0.74 cmolkg-1), respectively for AUL, BUL and YUL, respectively. The CEC ranges for AUL, BUL and YUL were 5.18-5.42 (mean, 5.32 cmol-1kg) 4.94-5.38 (mean, 5.2cmolkg-1) and 5.46-5.88 (mean, 5.65cmolkg-1) respectively. The CEC values 0f pedons AUL and YUL increased progressively with increasingly death. PBS ranged from 48-74 (mean, 58%), 52-68 (mean, 63%) and 65-66 (mean, 69%) for AUL, BUL and YUL in AAZ, BAZ and YAZ, respectively. PBS ranged from 48-74 (mean 58%) 52-68 (mean, 63%) and 65-66 (mean, 65%) in pedons AUL, BUL and YUL of AAZ, BAZ and YAZ of Kebbi state respectively. The pH values ranged from 5.4-5.6 (5.5), 4.5-5.2 (4.7 and 6.5-6.7) (mean, 6.7) for AUL, BUL, and YUL respectively. The mean EC values were 0.2dsm^{-1} and 0.5dsm^{-1} for AUL, BUL, and YUL respectively. The values for ESP were 11-16 (mean, 13%), 9-12 (mean 10% and 12-14 (13%) for AUL. BUL and YUL, respectively.

Recommendations

1. Based on soil texture of the upland soils of AAZ and BAZ, organic matter could be added to the soils to improve the texture and structure of the soils for sustainable crop production.

2. Based on the values of exchange bases and obtained CEC, the soil could be said to be medium in fertility and therefore appropriate management practices such as addition of organic matter, crop rotation, fallow periods, application of fertilizer and growing of leguminous crops should be applied on the soil for the sustainable agricultural Production.

3. Based on the concentration of pH, EC and ESP, the soil could be considered free form salinity and sodicity hazards and therefore good for crop production under appropriate management practices.

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