

Evaluation on fertility potentials of some soils in Gashaka local government area of Taraba State, Nigeria

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Abstract:

Field works were conducted to the study fertility potentials of some soils in Gashaka Local Government Area of Taraba State. Soil samples were collected from four selected wards; Gangumi, Garbabi, Jamtari and Gayam, using cropping systems as criteria for collection. Four profile pits were sunk in each of the wards and twelve (12) augering points, three in each ward at a distance of 2.5 km away from the pit. Soils were analyzed for morphological, physical and chemical properties. Results obtained revealed that the soils are deep (>1.6 m), and the soils are generally sandy loam textured with a moderately medium sub-angular blocky structure. Soils are yellowish brown (10YR 5/6) and strong brown (7.5YR) when moist to reddish in colour (2.5YR) under dry conditions at the surface indicative of prevalence of Fe (III) and Fe (II) oxide with bulk density mean values of 1.55 and 1.60gcm³ for pedons and augered samples respectively with mean porosity of 46% for all the samples. Chemical properties shows that the pH of the soils is moderately acidic (5.50 to 6.64) to neutral with low to moderate EC values in pedons and augered samples respectively. Organic carbon and net nitrogen averaged 9 g/kg and 6 mg/kg respectively. Available P averaged 3.7 and 0.84 mg/kg for pedons and augered samples respectively. Exchangeable acidity, total exchangeable bases and exchangeable sodium percentage (ESP) were low while effective cation exchange capacity (ECEC) was moderate to high in all the samples. The soils of the four districts are deep, moderate in structure and well drained with, low to medium organic carbon, N, P and K contents indicated medium fertility levels, and could be maintained and sustained through monitoring and balanced integrated nutrient management using both synthetic and organic fertilizers.

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1. Introduction

Land resources, soils continue to be the most valuable. For this reason, regular assessments of soils are crucial to ensuring sustainable crop production on a national and international level, as well as food security across the African continent. The continent, and Nigeria in particular, have soil that primary factor influencing agricultural productivity is fertility. Tropical savanna soils have been reported to be inherently low in fertility status [1]. The inherently low fertility status, continuous cultivation, poor fertilizer management and other anthropogenic factors have further depleted the soil resources with consequent effects on their productive potentials which are influenced by morphological, physical and chemical properties. However, despite the low fertility status stated, there is scarcity of soil data on soils of Northern Nigeria, soils of Northern Nigeria in general while little effort is made towards re-evaluating the land resources of the region at micro-scale. With geometric increase in demand for land resources due to growing population, industrialization and urbanization, the need for inventory of soil resources as it relates to potential fertility

with a view to improving and sustaining food production is very much vital for achieving global and national food security through improved soil management. In addition, the data generated would serve as a substitute to regularize fertilizer trials for fertilizer recommendations. The general works classification and fertility limitations of the general works of Musa, et al. [2] classification and fertility limitations of the soils particularly relating to potential fertility status and capability to sustained crop production.

2. Materials and methods

2.1 Location and extent of the study area

The study was carried out in Gasaka local government are of Taraba state covering four villages of different districts in the local government; Gangumi, Garbabi, Jamtari, and Gayam. Gashaka local government is located between latitudes, 7° 28' and 12 ° 27" N, and longitudes 11° 31' and 21° 38' E within the Savannah woodland zone of Nigeria [3]. It lies at an elevation of 501.0912m above sea level, situated about 120km away

from Jalingo the Capital city of Taraba State in the Northern Guinea Savanna Zone of Nigeria. Figure 1 shows Map of Gashaka Local Government area showing the study area. Soil samples were collected using soil auger in each of the four selected wards. Three profile pits were sited and dug in each of the wards with a dimension of 1.5m x 2m x 2m and soil samples were collected from different identified horizons. Surface (0 - 20) and sub-surface (20 - 50) soil samples were also collected at a distance of 5 km away to left and right of each sited pit Samples. Pit sample were five (5) in Gangumi and Garbabi area while Jamtari has three (3) sample and Gayam has four (4) sample per area. The total Number of samples as a whole is 41.

2.2 Soil sampling and laboratory analysis

The total number of samples as a whole is 41. Sample collected were air dried, crushed, sieved, labeled and taken to the laboratory for physical and chemical analysis. Particle size distribution was determined using Bouyoucos hydrometer method as described by Pune, *et al.* [4]. The soil color was determined using Munsell color chart both in the dry and wet state. Soil pH and EC were measured in 1:2 soil to water ratio using pH and digital conductivity meters respectively.

Calcium and magnesium were determined using titrimetric method with 1N Ammonium acetate. Potassium and sodium were determined using Flame Photometer. Titrimetric method was used to determine aluminum and hydrogen ions as described by Pune, *et al.* [4]. The organic

carbon of the soils were determined using Walkley and Black Potassium dichromate wet oxidation method as described by Pune, *et al.* [4]. The Bray 1 method was used for the determination of available phosphorus content of the soil. Total exchangeable bases (TEB) were calculated by the summation of sodium, potassium, calcium and magnesium. The exchangeable sodium percentage (ESP) content was obtained by calculating and dividing the exchangeable sodium content of the soil by the TEB (soil), and was expressed in percentage. Summation method as also described by Pune, *et al.* [4] was followed to obtain the ECEC. Base saturation was calculated by dividing the sum of TEB by the ECEC, and was expressed in percentage. Soil data were analyzed using statistix 8.0 softwares.

3. Results and discussion

3.1 Morphological properties of the soils

The results of morphological properties of the study area are presented in Table 1. The soils are moderately deep with noticeable horizons. Soils are yellowish brown to reddish in color in all the sampling areas. The dominantly reddish brown color recorded in all the pedons of Gangumi, Garbabi, Jamtari, and Gayam may be attributed to the presence of Fe (III) and Fe (II) depending on oxidation-reduction reaction conditions which might have been influenced by the moisture condition in the soil of the study area.

Table 1: Soil Physical Properties of the Pedon

Pedon (cm)	Sand (%)	Silt (%)	Clay (%)	Textural Class	Colour (wet)	Colour (dry)	Bulk density (g/cm ³)	Porosity (%)
Gangumi								
0-20	82.4	12.4	5.2	loamy sand	2.5YR 4/3	10YR 5/6	1.69	36
20-55	78.4	11.6	10	loamy sand	5YR 5/4	10YR 5/6	1.58	40
55-105	70.8	10.4	18.8	loamy sand	2.5YR 6/6	5YR 6/6	1.48	44
105-140	80.4	12.4	7.2	loamy sand	10R 6/8	5YR 6/8	1.63	38
140-200	76.8	10	13.2	loamy sand	5YR 5/8	7.5YR 6/8	1.54	42
Mean	77.8	11.36	10.9	loamy sand			1.58	40
Garbabi								
0-20	82.4	12	5.6	loamy sand	2.5YR 4/2	10YR 4/6	1.68	37
20-40	70.4	12.8	16.8	loamy sand	7.5YR 4/6	7.5YR 4/6	1.49	44
40-75	66.8	11.2	22	sandy loam	5YR 5/8	5YR 5/8	1.44	45
75-90	66.8	15.6	17.6	sandy loam	5YR 5/6	10YR 6/8	1.48	44
90-200	82.4	12.4	5.2	loamy sand	5YR 5/6	2.5Y 6/8	1.69	36
Mean	73.8	12.8	13.4	loamy sand			1.56	41
Jamtari								
0-20	80.4	14.4	5.2	loamy sand	2.5YR 4/3	10YR 5/6	1.68	37
20-75	75.6	15.2	9.2	loamy sand	5YR 5/4	7.5YR 6/8	1.59	40
75-200	62.2	13	24.8	sandy loam	10R 6/8	2.5YR 5/8	1.42	46
Mean	72.7	14.2	13.1	loamy sand			1.56	41
Gayam								
0-20	72.4	20.4	7.2	loamy sand	2.5YR 5/1	2.5Y 5/6	1.62	39
20-60	58.4	18.4	23.2	sandy loam	10YR 7/4	10YR 5/8	1.42	46
60-130	60.4	13.2	26.4	sandy loam	7.5YR 8/1	2.5 Y 5/6	1.41	47
130-200	62.2	18.2	19.6	sandy loam	7.5YR 8/2	2.5Y 7/6	1.45	45
Mean	72.68	13.59	13.73	loamy sand			1.55	41.4

Joshi, *et al.* [5] reported that tropical soils with clayey texture under anoxic condition are usually dominated with ferric iron, hence the reddish coloration. Daunoras, *et al.*

[6] attributed yellow colouration of soils to oxidized state of iron. Guo, *et al.* [7] while studying soils derived from basalt in the North Eastern Nigeria observed that there was

prevalence of Fe (III) and Fe (II) in pedons that have undergone redox reactions.

Kemp, et al. [8] reported strong brown (7.5YR 5/6) sandy surface horizons over yellowish red (5YR 4/8) sandy loam subsurface horizons in the soils of Bali sand plains, North Eastern Nigeria. However, Ahmed, et al. [9] reported that Ap horizons of some selected Kwara State soils southern guinea savannah to be dark coloured with values and chromas not exceeding 4. Variable colours were however reported at the subsurface [9]. Similarly, Ding, et al. [10] indicated that the soils of marke, southern guinea savannah were dominantly dark brown (7.5YR) to

yellowish brown (10YR). The clearly developed horizons observed in the pedons are indication of fully developed soils that had undergone long period of pedogenesis. Kemp, et al. [8] revealed that pedogenic horizons develop over a long period of time during soil formation.

3.2 Soil Physical properties

The results of the physical properties of the soils of Gangumi, Garbabi, Jamtari, and Gayam are presented in Table 2.

Table 2: Soil Physical Properties of Augered Samples

Sample	Sand (%)	Silt (%)	Clay (%)	Textural class	Bulk density (g/cm ³)	Porosity (%)
Gangumi						
Gan1A	69.2	24	6.8	sandy loam	1.62	39
Gan1B	43.2	22	34.8	clay loam	1.33	50
Gan2A	67.2	26	6.8	sandy loam	1.62	39
Gan2B	43.2	24	32.8	clay loam	1.34	49
Gan3A	65.2	28	6.8	sandy loam	1.61	39
Gan3B	41.2	24	34.8	clay loam	1.33	50
Mean	65.8	30	24.6		1.45	44.33
Garbabi						
Gar1A	47.2	36	16.8	Loam	1.45	45
Gar1B	37.2	24	38.8	clay loam	1.3	51
Gar2A	45.2	36	18.8	Loam	1.43	46
Gar2B	41.2	24	34.8	clay loam	1.33	50
Gar3A	53.2	32	14.8	sandy loam	1.48	44
Gar3B	39.2	22	38.8	clay loam	1.48	44
Mean	52.6	35	32.6		1.41	47
Jamtari						
Jam1A	49.2	36	14.8	Loam	1.57	45
Jam 1B	49.2	30	20.8	Loam	1.42	46
Jam 2A	47.2	38	14.8	Loam	1.47	45
Jam 2B	47.2	28	24.8	Loam	1.39	48
Jam 3A	41.2	38	20.8	Loam	1.4	47
Jam 3B	49.2	30	20.8	Loam	1.42	46
Mean	56.6	40	23.4		1.45	46
Gayam						
Gay1A	73.2	22	4.8	sandy loam	1.68	37
Gay 1B	65.2	22	12.8	sandy loam	1.52	43
Gay 2A	73.2	18	8.8	sandy loam	1.59	40
Gay 2B	67.2	20	12.8	sandy loam	1.52	42
Gay 3A	73.2	20	6.8	sandy loam	1.63	39
	63.2	16	20.8	sandy clay loam	1.45	45
Mean	83.0	23.6	13.4		1.57	41

The soil pedons are dominantly loamy sand at the surface in Gangumi, Garbabi, Jamtari, and Gayam (Table 2). However, clay loam texture was dominant at the subsurface layer of Gangumi and Garbabi, augered points (Table 1), indicative of clay and Fe-hydroxides eluviation illuviation process which may be due to the dominant factor influencing soil formation, and the comparatively high precipitation levels being recorded in the area each season. Similar characteristics were reported to have been exhibited by soils of Sokoto sand plains [1]. Bulk density of the soils ranged from 1.50 g/cm³ to 1.69g/cm³ with a mean value of 1.60g/cm³ (Table 2) in the pedons with highest value of 1.69g/cm³ at the surface in Jada, and lowest value of 1.50g/cm³ was recorded at the depth of 55 to 105 cm. In Jamtari, the bulk density ranged from 1.44 to

1.69 g/cm³ with a mean value of 1.56 g/cm³ in both pedons and augered samples with comparatively lower bulk density values in the augered sample points. In Garbabi however, the bulk density in the pedons ranged from 1.42 to 1.68 g/cm³ with mean value of 1.56 g/cm³. High bulk density of 1.68 g/cm³ was recorded at 0 to 20cm. In Gayam, the soils are sandy loam in texture (Table 2). The bulk density in the pedons ranged from 1.41 to 1.62 g/cm³ with a mean value of 1.47 g/cm³ (Table 2) while the augered samples have bulk density ranging from 1.30 to 1.68 g/cm³ with a mean value of 1.48g/cm³ (Table 3). The highest value of 1.68g/cm³ was recorded at Garbabi in the surface layer (Table 2). The lowest bulk density of 1.30 g/cm³ was recorded at Gayam in the subsurface layer (Table 2) in the augered samples.

Table 3: Soil Chemical Properties of the Pedons

Pedon	pH	EC	TDS	OC	NH ₄ ⁺	NO ₃ ⁻	Net N	AVP	Na ⁺	K ⁺	Ca ²⁺	Mg ²⁺	TEB	H ⁺	Al ³⁺	TEA	ECEC	BS	SAR	ESP
	1:02	(dS/m)	(ppm)	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	cmol/kg									(%)		(%)
Gangumi	6.2	0.4	256	0	3.2	4.6	7.7	3.6	1.2	0.2	1.8	1.1	4.3	0.8	2.4	3.2	7.5	57.5	1.0	27.5
0-20	6.6	0.5	332.8	1.1	2.8	1.4	4.2	2.4	1.2	0.1	2	0.9	4.2	0.4	1.2	1.6	5.8	72.5	1.0	28.2
20-55	6.4	0.4	243.2	0.5	1.1	3.9	4.9	0.4	1.3	0.3	1	1.6	5.1	4.4	4.4	4.4	9.5	53.5	1.0	25.5
55-105	6.3	0.2	128	1.2	4.6	3.9	8.4	0.1	1.3	0.2	2.3	0.7	4.4	0.8	0.8	1.6	6	73.3	1.0	28.4
105-140	6.6	0.4	230.4	0.4	5.1	5.5	10.5	0.5	1.4	0.1	3	0.6	5.2	3.2	3.2	3.2	8.4	61.8	1.1	27.7
140-200	6.4	0.4	238.1	0.6	3.3	3.8	7.1	1.4	1.3	0.2	2	1	4.6	1.9	2.4	2.8	7.4	63.7	1.0	27.4
Garbabi	6.1	0.7	448	0.6	2.8	5	7.8	2.1	1.2	0.4	4.4	2	8	0.4	2.4	2.8	10.8	74	0.7	15.3
0-20	6.1	0.6	396.8	0.5	4.2	4.9	9.1	0.8	1.3	0.5	3.2	1.4	6.4	1.2	2.8	4	10.4	61.6	0.9	20.4
20-40	6.3	0.3	166.4	0.7	2.8	5	7.8	0.2	1.3	0.2	3	1.8	6.3	0.4	1.2	1.6	7.9	79.8	0.8	20.3
40-75	6.2	0.5	294.4	1	5.5	4.9	10.4	1.1	1.4	0.3	2.9	2.7	7.3	0.4	2	2.4	9.7	75.1	0.8	18.6
75-90	6.4	0.4	243.2	0.8	2.8	4.7	7.5	0.7	1.3	0.2	2.5	1.6	5.6	0.8	2.8	3.6	9.2	60.7	0.9	22.7
90-200	6.2	0.5	309.8	0.7	3.6	4.9	8.5	1	1.3	0.3	3.2	1.9	6.7	0.6	2.2	2.9	9.6	70.2	0.8	19.5
Jamtari	6.3	0.4	230.4	0.6	4.7	4.9	9.6	0.8	1.3	0.2	2.3	0.4	4.1	0.8	2.4	3.2	7.3	56.2	1.1	30.5
0-20	5.9	0.1	76.8	0.7	3.5	3.2	6.7	0.8	1.3	0.1	2.4	1.1	4.9	0.4	2.4	2.8	7.7	63.8	1.0	26.5
20-75	6.1	0.3	192	0.5	1.8	0.7	2.5	0.9	1.4	0.2	2.7	1	5.2	0.4	2.4	2.8	8	65.3	1.0	26
75-200	6.1	0.3	166.4	0.6	3.3	2.9	6.2	0.9	1.3	0.2	2.5	0.8	4.8	0.5	2.4	2.9	7.7	61.8	1.0	27.7
Gayam	6.2	0.3	166.4	1.2	5	5	10	0.4	1.2	0.1	2.6	1.7	5.7	0.8	2.8	3.6	9.3	61.1	0.8	21.6
0-20	6.5	0.2	128	1.1	1.8	3.9	5.6	0.1	1.3	0.3	3.8	2.8	8.1	1.2	2	3.2	11.3	71.8	0.7	15.9
20-60	6.4	0.4	281.6	1.4	5.3	3.5	8.8	1.4	1.4	0.3	6.8	3.2	11.7	0.4	2.4	2.8	14.5	80.7	0.6	12
60-130	6.4	0.6	358.4	1.1	5	2.8	7.8	1.2	2.2	0.5	5.7	4	12.4	0.4	3.6	4	16.4	75.6	1.0	17.7
MEAN	6.3	0.4	244.4	0.8	3.6	4.0	7.6	1.0	1.3	0.2	3.0	1.6	6.3	1.0	2.4	3.0	9.2	67.0	0.9	23.0

Table 4: Chemical Properties of the Augered Samples

Samples	pH (1:2)	EC (dS/m)	TDS (ppm)	OC (%)	Net-N (mg/kg)	AVP (mg/kg)	Ca ²⁺	Mg ²⁺	Na ⁺	K ⁺	TEB	TEA	ECEC	BS	SAR	ESP
							Cmol/kg									
Gangumi	6.4	0.7	448.0	1.4	3.0	3.3	2.4	0.4	0.1	0.3	3.2	1.0	13.2	24.3	0.1	4.1
Gan1A	6.4	0.8	512.0	0.7	4.0	4.2	7.2	0.6	0.3	0.3	8.4	0.6	14.4	58.4	0.2	4.1
Gan1B	6.4	0.5	320.0	0.9	4.0	3.8	4.8	0.5	0.4	1.5	7.2	1.4	21.2	33.8	0.2	5.5
Gan2A	6.3	0.9	569.6	0.9	4.0	3.7	4.0	0.9	0.3	0.3	5.4	1.4	19.4	28.0	0.2	4.8
Gan2B	6.3	0.7	460.8	0.9	3.0	3.1	7.2	1.2	0.3	1.0	9.7	0.8	17.7	54.7	0.1	2.7
Gan3A	6.2	0.8	480.0	0.6	4.0	3.0	4.0	0.7	0.2	0.6	5.5	1.0	15.5	35.3	0.1	3.2
Gan3B	6.3	0.7	465.1	0.9	4.0	3.5	4.9	0.7	0.3	0.6	6.6	1.0	16.9	39.1	0.2	4.1
Garbabi	6.2	0.8	524.8	1.2	2.0	3.7	4.8	1.3	0.2	1.2	7.5	1.4	21.5	34.7	0.1	2.3
Gar1A	7.4	0.8	492.8	1.0	3.0	6.2	8.8	1.3	0.5	0.9	11.5	1.2	23.5	48.9	0.2	4.5
Gar1B	6.7	0.8	499.2	1.1	4.0	3.5	7.2	0.3	0.2	0.5	8.2	1.2	20.2	40.6	0.1	2.1
Gar2A	7.6	0.7	460.8	1.4	4.0	9.1	9.6	1.7	0.4	0.9	12.7	0.6	18.7	67.8	0.2	3.4
Gar2B	6.8	0.8	480.0	1.2	3.0	3.0	8.0	0.3	0.3	0.6	9.2	1.4	23.2	39.5	0.1	2.9
Gar3A	7.5	0.7	416.0	1.0	3.0	1.1	8.0	1.3	0.6	0.7	10.6	0.6	16.6	63.8	0.3	5.3
Gar3B	7.0	0.7	478.9	1.2	3.0	4.4	7.7	1.0	0.4	0.8	9.9	1.1	20.6	49.2	0.2	3.4
Jamtari	6.8	0.8	492.8	1.7	4.0	3.1	7.2	0.8	0.2	0.4	8.7	2.0	28.7	30.2	0.1	2.5
Jam1A	6.3	0.8	492.8	1.0	3.0	3.7	2.4	1.3	0.2	0.4	4.3	1.0	14.3	30.0	0.1	4.1
Jam 1B	6.9	0.8	505.6	1.6	6.0	3.1	9.6	0.5	0.3	0.4	10.7	1.0	20.7	51.7	0.1	2.4
Jam 2A	6.2	0.9	550.4	0.6	3.0	3.8	4.0	0.7	0.4	0.4	5.5	0.6	11.5	47.8	0.3	7.1
Jam 2B	6.6	0.8	480.0	1.3	4.0	3.7	6.4	0.9	0.1	0.5	7.9	2.0	27.9	28.4	0.1	1.6
Jam 3A	6.3	0.7	467.2	0.7	4.0	3.7	3.2	0.4	0.1	1.2	4.9	1.8	22.9	21.3	0.1	2.7
Jam 3B	6.5	0.8	498.1	1.1	4.0	3.5	5.5	0.8	0.2	0.5	7.0	1.4	21.0	34.9	0.1	3.4
Gayam	6.3	0.8	524.8	1.1	3.0	3.1	11.2	1.0	0.1	1.9	14.1	1.4	28.1	50.2	0.0	0.3
Gay1A	6.2	0.8	512.0	0.9	3.0	2.6	7.2	0.3	0.2	0.8	8.5	1.2	20.5	41.4	0.1	2.1
Gay 1B	6.5	0.7	422.4	1.2	3.0	3.5	3.2	0.5	0.3	1.8	5.8	1.4	19.8	29.4	0.3	6.0
Gay 2A	6.3	0.8	531.2	0.6	3.0	3.0	6.4	0.1	0.1	1.9	8.5	1.4	22.5	37.9	0.1	1.5
Gay 2B	6.7	0.8	480.0	0.5	2.0	4.1	4.0	0.4	0.5	0.7	5.5	0.6	11.5	48.0	0.3	8.6
Gay 3A	7.3	0.7	441.6	0.7	2.0	4.8	0.8	1.5	0.2	1.8	4.3	1.2	16.3	26.4	0.2	5.0

The bulk density decreased with increasing depth in Gangumi soil pedon. The consistently higher bulk density at the surface and lowest at the sub-surface may be attributed to high cultivation and compaction at the surface layer. Ding, *et al.* [10] reported that rain drop impact and cultivation increased bulk density of soils. Similarly, Pune, *et al.* [4] reported increased bulk density due to soil cultivation and compaction.

The low bulk density at the sub-surface may however be related to the lower organic matter content at the surface in addition to zero cultivation at the subsurface. Lal [11] reported bulk density value of 1.55 g/cm³ and as high as 1.78 g/cm³ at surface and subsurface horizons respectively for soils of Sokoto plains, Northern Guinea Savannah. Lower bulk density value of 1.4 g/cm³ was reported for soils of Mambila plateau in Gelybó, *et al.* [12]. Much lower mean bulk density value of 1.35 g/cm³ was also reported by Gelybó, *et al.* [12] for soils of Jiwa Sourthen Guinea Savannah, Nigeria. Unlike the high bulk density recorded at the surface, a slightly higher porosity was recorded at the sub-surface depth of 55 to 105 cm with a percent porosity of 44% (Table 2). This may be due to the lower bulk density recorded at the sub-surface. In addition, there was lower organic matter content at the sub-surface compared to the surface horizon, thus resulting in higher soil porosity [3].

The percentage porosity ranged from 36 to 44% with a mean value of 41.6%. The porosity increased with increasing depth which may be due to the reduced compaction. Percentage porosity in the pedons ranged from 39 to 47% with a mean value of 44.25%, and ranged from 37 to 51% with a mean value of 44% in the augered samples (Table 3). The highest value of 51% was recorded at Garbabi in the subsurface layer (Table 2), and the lowest of 37% was in the surface layer of Gayam (Table 2). High and low porosity values have also been reported by many authors such as Veni, *et al.* [13].

3.3 Soil Chemical properties

The chemical properties of the pedons 1, 2, 3, and 4 and augered samples are presented in Tables 3 to 4. Soil pH ranged from 5.90 to 6.64 with a mean value of 6.30, and 6.2 to 7.60 with a mean value of 6.60 for pedons and augered samples respectively. The highest value of 7.60 recorded in Gayam at subsurface layer in the pedons (Table 2). The pH is rated moderately to slightly acidic [7]. Slightly acidic pH ranges have severally been reported to be optimum for nutrient release and use for plant growth and development [7].

However, the highest pH recorded in the augered samples (Table 7) may be due to the leaching of exchangeable bases down to the sub-surface horizon which may be as a result of high infiltration, and continuous cultivation as a consequence of high precipitation levels at a time. In addition, since the soils are dominantly sandy loam, the texture might have contributed to increased porosity and leaching of bases. High moisture content accompanied by high soil porosity accelerates leaching of bases [13]. Tropical soils are mostly acidic due to the dominance of iron and aluminium in the colloidal complex.

EC ranged from 0.12 to 0.62 dSm⁻¹ with a mean value of 0.38 dSm⁻¹ and 0.5 to 0.9dSm⁻¹ with a mean value of 0.75 dSm⁻¹ for pedons and augered samples respectively. The highest EC value of 0.62dSm⁻¹ was recorded at the depth of 20 to 40 cm in Gayam (Table 3), while the lowest value of 0.12dSm⁻¹ was recorded at 20 to 75 cm depth in Garbabi (Table 3). Soil EC values of < 0.4dSm⁻¹ is rated non-saline, and therefore safe for crop production Bruun, *et al.* [14]. Similar results of 0.027 to 0.2 dSm⁻¹ were recorded in Marke, Nigeria by Caplan, *et al.* [15]. The organic carbon content values of the pedons ranged from 0.4 to 13.5 g/kg with a mean value of 7.8 g/kg (Table 5). Organic carbon content values were higher at subsurface depth but lower at pedons 1 and 3 (Table 4). Contrary results were recorded in pedons 2 and 4 (Table 3). The lower organic carbon values recorded at the surface horizon of pedon 1 and 3 compared to the sub-surface may be due to ploughing with resultant effect of turning the lower layer up. Hicks, *et al.* [16] reported that intense land clearing and ploughing upturn soils of the tropics, and transport the organic residues to the lower horizon.

The augered samples analyzed shows that the organic carbon content values were generally higher at the surface (Table 4) compared to the sub-surface, and ranged from 5 to 17 g/kg (Table 9). Organic carbon content values in both the pedons and augered samples were less than 20 g/kg (Table 3 and 4). Lal [11] Reported similar values for tropical soils. Similarly, Joshi, *et al.* [5] reported similar low organic carbon content values for the Nigerian savannah soils. Mean organic carbon content of 6.5 g/kg was reported by Musa, *et al.* [2] for soils of Jiwa, Southern Guinea Savannah.

The available nitrogen or mineralizable nitrogen comprising of NH₄-N and NO₃-N ranged from 4.2 to 10.5 and 3 to 6.2 mg/kg in pedons and augered samples respectively (Table 3 to 4). The results show low levels of available nitrogen in the soils of the area. It was also reported that the extent to which mineralizable nitrogen accumulates is related to the nutrifiable N in the soil which has be a function of the amount and nature of the organic matter particularly the carbon to nitrogen ratio. In Kogi west, Blanco-Canqui *et al.* [18] reported a similar value of <1.5 gkg⁻¹. Available phosphorus ranged from 0.14 to 3.57 mgkg⁻¹ with a mean value of 0.84 mgkg⁻¹, and 1.1 to 9.1 mgkg⁻¹ with a mean value of 3.7 mgkg⁻¹ for pedons and augered samples respectively (Table 3 to 4). Lower available phosphorus contents were recorded in the pedons compared to the augered samples. This may be due to mining by plants as a consequence of continuous cultivation in the area where auger samples were collected as well as the sandy loam nature of the soils that allow nutrient movement beyond the root zone. Low AVP (< 10cmolk⁻¹) were reported for Demsa soils of Nigeria by Blanco-Canqui *et al.* [18].

The exchangeable bases; calcium, magnesium, potassium and sodium recorded in both the pedons and augered (Table 3 and 3) samples were generally medium to high indicative of prevalence of the bases in the colloidal complex. Calcium ranged from 1.0 to 6.8 cmolk⁻¹ with a mean value of 3.08 cmolk⁻¹; the highest value of calcium

was recorded at a depth of 60 to 130 cm in Garbabi, and the lowest in Jada at a depth of 55 to 105 cm. Magnesium ranged from 0.4 to 4.0 cmolkg⁻¹ with a mean of 1.68 cmolkg⁻¹; the highest value was recorded in Gayam at a depth of 130 to 200 cm, and the lowest value in Jamtari at a depth of 0 to 20 cm. Potassium ranged from 0.13 to 0.50 cmolkg⁻¹ with mean value of 0.24 cmolkg⁻¹; the highest value was recorded in Gayam at a depth of 130 to 200 cm. Sodium ranged from 1.19 to 2.2 cmolkg⁻¹ with a mean value of 1.35 cmolkg⁻¹; the highest was recorded in Jamtari at a depth of 130 to 200 cm, and the lowest was in Jada at a depth of 0 to 20 cm and 20 to 55 cm. The exchangeable bases recorded in the lower horizons in both pedons and augered samples may be attributed to the leaching of the bases down to the subsurface particularly where high moisture condition prevails. Similar exchangeable bases values were reported by Lidón and Serra [18] for soils of Demsa Northern Guinea Savannah. However, except for K, much lower values were earlier reported by Bruun, *et al.* [14] for soils of Dalah, Sokoto, Northern Guinea Savannah. Exchangeable acidity (EA) ranged from 1.6 to 4.4 cmolkg⁻¹ with a mean value of 2.97 cmolkg⁻¹ in the pedons (Table 3). The highest value of 4.4 cmolkg⁻¹ was recorded in Jada at a depth of 55 to 105 cm while the lowest value of 1.6 cmolkg⁻¹ was recorded in Gangumi and Garbabi at the depths of 20 to 55 cm and 40 to 75 cm respectively. The augered samples ranged from 0.6 to 2.0 cmolkg⁻¹ with a mean of 1.17 cmolkg⁻¹ (Table 4). The highest value of 2.0 cmolkg⁻¹ was recorded in Jamtari. The TEA is thus rated low by Blanco-Canqui *et al.* [17] and may probably be due to low exchangeable acidic cations (H⁺ and Al³⁺) at the exchange site of the soil colloidal complex [19]. The ECEC ranged from 5.82 to 16.4 cmolkg⁻¹ with a mean value of 9.40 cmolkg⁻¹ in the pedons. The highest value of 16.4 cmolkg⁻¹ was recorded in Garbabi at a depth of 130 to 200 cm, and the lowest value of 5.82 cmolkg⁻¹ was recorded in Jada at the depth of 20 to 55 cm. In the augered samples, ECEC ranged from 11.54 to 28.65 cmolkg⁻¹ with a mean of 19.58 cmolkg⁻¹ with the highest value of 28.65 cmolkg⁻¹ recorded in Garbabi soils, and the lowest value of 11.54 cmolkg⁻¹ recorded in Gayam (Table 4). Ahmed, *et al.* [9] reported a mean value of 14.6 cmolkg⁻¹ for semi-arid soils of Borno state. However, comparatively lower ECEC mean value (<10 mg/kg) was reported by Mondal, *et al.* [20]. The ECEC of the soils of the four districts is thus rated high [6]. The PBS ranged from 53.49 to 80.73% with a mean value of 67.31% in the pedons. The highest value of 80.73% was recorded in Garbabi at the depth of 60 to 130 cm, and the lowest value of 53.49% was recorded in Jada at a depth of 55 to 105 cm. In the augered samples, percent base saturation (PBS) ranged from 21.34 to 67% with a mean value of 40.52%. Earlier, similar PBS ranges and mean values were reported by Joshi, *et al.* [5] for some selected soils in Gashaka Local government Taraba State. Thus, the PBS of the soil is rated medium to high [7].

Exchangeable sodium percentage ranged from 12.02 to 30.49% with a mean value of 22.84% in the pedons (Table 2). The highest value of 30.49% was recorded in Gayam at the depth of 0 to 20 cm, and the lowest value of 12.02% was recorded in Garbabi at the depth of 60 to 130 cm. ESP ranged from 1.53 to 8.63% with a mean value of 3.7%

in the augered samples. A similar range of 0.4 to 2.5% with a mean of 1.3% was reported by Mondal, *et al.* [20] for Muchalla Flood plain in Mubi-North, Adamawa State. Similarly, a mean value 1.10% was reported by Musa, *et al.* [2] while evaluating some selected soils in Gashaka, Taraba state. Therefore, the ESP of the soils of the four districts is rated low [7], and is unlikely to exert any negative effect on soil and plants.

3.4 Soil variability

Soil physical properties show insignificant variation in texture within and amongst pedons. Similarly, there was no significant variation of bulk density in surface and subsurface in both pedons and augered samples (Table 2 and 3). However, there was variability of bulk density within pedons (Table 2). Porosity markedly varies in the pedons. Similarly, there was also marked variability of soil colour in the soil pedons. Variability of soil chemical properties shows that except for EC, Na and TEA, there was significant ($P < 0.05$) variation of pH, TDS, AV-N, AVP, Ca, Mg, K, TEB, ECEC BS and ESP amongst the locations. The implication of the variability in these soil properties is that with similarity in organic carbon content, mineralizable (Net nitrogen), available phosphorus, and potassium contents in all the four districts, similar fertilizer requirements for improved crop production may be required. However, high variability in colour, TDS, calcium, TEB, ECEC, BS and ESP particularly at surface and subsurface requires close monitoring to avoid nutrient imbalances. Monitoring soil moisture condition is imperative to reduce the negative effects of anoxic condition which facilitates the conversion of Fe (II) to (Fe III) with consequent negative effects on crop performance.

3.5 Fertility status of soils

In pedon 1, the pH is slightly acidic. The EC, AVP, TEB and ECEC were all medium, while organic carbon is medium to high. Base saturation and ESP were high. The soils have high bulk density and a mean porosity value of 40%. The soils are mostly silty clay with slightly sticky consistency and moderate medium sub-angular blocking structure. Therefore, the soils in this pedon are of medium fertility. In pedon 2, the pH is slightly acidic with low EC, AVP, TEB and ECEC but with medium organic carbon and high BS and ESP. The soils have high bulk density and a mean porosity of 41.6%. The soils are mostly clay with slightly sticky consistency and moderate medium angular blocking structure. Therefore, the soils in this pedon are of medium fertility. In pedon 3, the pH is slightly acidic with low EC, AVP, TEB and ECEC but with medium organic carbon and high BS and ESP. The soils have moderate to high bulk density and a mean porosity of 41%. The soils are all clayey in texture with slightly sticky consistency with a moderate to medium sub-angular blocking structure. Therefore, the soils in this pedon are also of medium fertility.

In pedon 4, the pH is slightly acidic with low EC, AVP and TEB but with medium ECEC and high OC, BS, and ESP. The soils have moderate bulk density and a mean porosity of 44.25%. The soils are all clay with very sticky

and very plastic consistency with a strong medium angular blocking structure. Therefore, the soils in the pedon are of medium fertility. The augered samples exhibited similar physical and chemical properties of the pedon thereby confirming the fertility status of the areas investigated. Overall, the four pedons and the augered samples analyzed indicated that the soils of the area are of medium fertility.

4. Conclusion

The soils are very deep with moderate texture and structure for smooth growth and development of crop plants. Similarly, pH, EC and all other critical soil fertility indices are favorable for crop production. Thus, the soils are of medium fertility and careful soil monitoring and improved management through balanced fertilization may maintain and sustain soil fertility, and also enhance soil productivity in the area.

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