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Evaluation of soil fertility potentials of Guyuk local government area of Adamawa State, Nigeria

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Abstract
This study was conducted to evaluate soil fertility potentials of Guyuk Local Government Area of Adamawa State, Nigeria. Stratified random sampling technique was used for soil sampling. Soil samples were collected from the seven districts (Boibini, Guyuk, Kurnyi, Banjiram, Chikila, Kola and Dumna districts) of the Local government based on variation in soil characteristics observed, Random samples were collected at surface (0 – 20 cm) and subsurface (20 – 50 cm). Ten profile pits were sunk at least one in each district and samples were collected from each horizon for laboratory analysis, Global Positioning System (GPS) was used for exact location and altitude of pedons. The soils were analysed to determine the morphological, physical and chemical properties. Results obtained revealed that soils of the study area averaged at 203m above sea level, soils are moderately deep and generally sandy loam to clay textured with weak to strong sub angular blocky structure. The soils are well drained to moderately drained with high chroma value of 7.5YR and 10YR. Bulk density and porosity of pedons and augered samples averaged at 1.40mg/kg and 47% respectively, chemical properties showed pH was near neutral, organic carbon, total nitrogen and exchangeable sodium percentage (ESP) were generally to be low, available phosphorus was generally moderate, total exchangeable bases (TEB), Base saturation, and effective cation exchange capacity (ECEC) were high in soils of all the district of the study area. The soils of Bobini and Guyuk districts area were classified as Alfisols while Kurnyi, Banjiram, Chikila, Kola and Dumna districts are all Vertisols, according to USDA Soil Taxonomy. Three fertility classes were identified which are "S dm", "C div" and "C divb". The soil fertility of the study area can be improved and managed through integrated nutrient management system (INM).

Keywords: *fertility potentials, soil, evaluation, agriculture, Guyuk.*

Introduction

Plants absorb essential elements through their root systems or their leaves in various forms. The soil contains large amounts of all the elements, but only a very small percentage of these total amounts are available to plant. The potential of a given soil to produce is referred to as productivity, whereas the contribution of soil to productivity is called fertility.

The availability of nutrients to plants is determined by the form and chemical properties of the element, the soil pH, interactions with soil colloids, microbial activity and soil physical conditions such as aeration, compaction, temperature, and moisture (Sonon and Kissel, 2009). However, the evolving knowledge of the nature and properties of soil has help in better articulation of the potentials and limitations of soils to compatible land use over the years. A thorough know-

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ledge of soil pedology and agronomy are important indices in most fertility studies since soil data provides bases for guiding variety of land applications (Esu, 1999). Fertility survey data are used in the interpretation of soil fertility status in terms of nutrient reserves, additions, transformations and consequent colossal losses through crop removals, leaching and erosion (Tekwa and Usman, 2006).

Tropical soils are inherently low in native fertility (Agboola 1986), inappropriate crop and soil management practices degrade the soil and deplete nutrients, and this is compounded by poor organic matter levels and destruction. Additionally, persistent negative imbalance of macronutrients in the soils arising from loss of nutrients through crop residue removal which is less than compensated for by the fertilizer application containing only some of the macro nutrients. This study intends to evaluate and classify the fertility potential of soils in Guyuk Local Government area. The soil fertility map produced will assist government to educate farmers through the agricultural extension agencies on crop and fertility suitability. In addition, the data generated will add to the existing soil data.

Materials and Methods

The Study Area

The study was conducted in Guyuk Local Government Area of Adamawa State, it covers an area of 757 km^2 about 75,700 hectares of land (NPC, 2011), which include both cultivated and fallow areas. The area is located between latitude 9^0 30' and10^0 00' north and longitude 11^0 30' and 12^0 00' East, (Ray, 1999). The study area has seven districts which are:- Bobini District, Guyuk District, Kurnyi District, Banjiram District, Chikila District, Kola District and Dumna District, it falls within the northern guinea savannah zone (Adabayo, 1998), the geology of the study area can be distinguished into four formations which are: the Bima Sandstone, the transitional formation (complex of marine and continental sediments), Basalt (and other volcanic rocks) and the alluvial deposits, Shobayo *et'al.*, (2016). The study area is drained through a network of seasonal streams radiating from the Lunguda plateau into the Benue River (Tukur, 1999)

Field work and soil sampling technique

Pre-field survey was carried out in the surveyed area involving gathering information from topographical maps, interviews and meteorological data. Also a reconnaissance soil survey was conducted to get general idea of the soils and its variation. The soils of study area can be clearly distinguished into seven (7) group based on the different variations of soils of the area, which coincides with the seven districts of the Local Government Area; Bobini district, Guyuk district, Kurnyi district, Banjiram district, Chikila district, Kola district and Dumna districts, thus, serves as the representative locations of the study. Stratified ramdom sampling technique was used for sampling as described by Jaiswal, (2003). From each representative location five (5) random samples were collected at the depth of (0 – 20cm) for surface and five (5) samples for sub-surface (20 – 50cm) with the use of a soil auger and hand trowel, these all together constitute a total number of seventy (70) augred soil samples. At least one profile pit was sunk and soil profile were described in respect of guidelines for soil description (Jahn, *et'al.,* 2006) and samples (disturbed and undisturbed) were collected from all horizons of each location. Soil samples collected were kept in polyethene bags and well labelled for laboratory analysis.

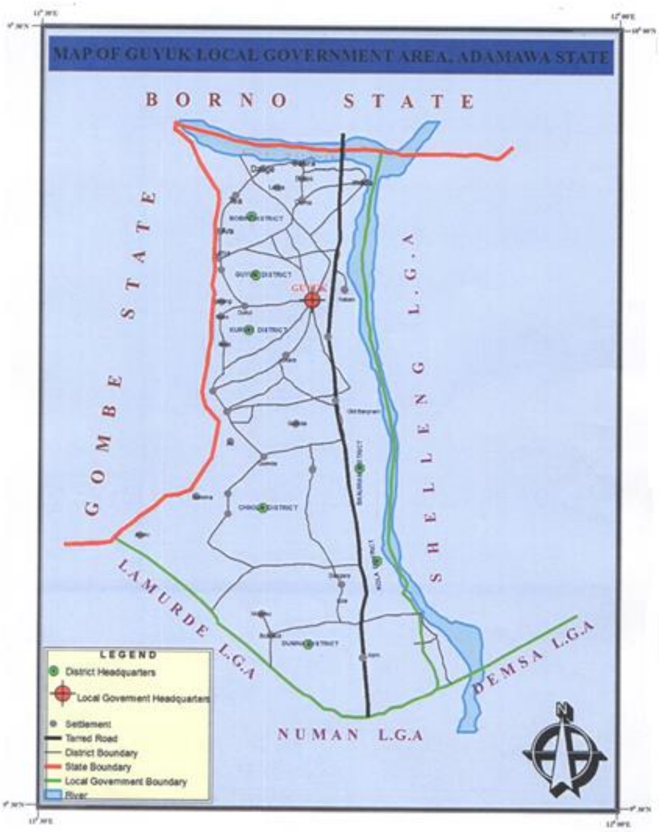

Figure 1. *Map of Guyuk local government*

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Laboratory Analysis

Particle size distribution was determined using Bouyoucos hydrometer method as described by (Jaiswal, 2004). Soil color was determined using Munsell color chart both in the dry and wet state. Soil structure, consistency and texture were described in accordance with Soil Survey Staff (2022). Soil pH and EC were measured in 1:2 soil to water ratio using pH and digital conductivity meters (model) respectively. Calcium and magnesium were determined using Ammonium acetate method (Black, 1965). Potassium and sodium were determined using flame photometer. Titration method was used to determine aluminum and hydrogen ions as described by Hesse (2002). The organic carbon of the soils were determined using Walkley and Black, Potassium dichromate wet oxidation method as described by Jaiswal (2004). The Bray 1 method was used for the determination of available phosphorus content of the soil (Bray and Kurtz, 1945). Total exchangeable bases (TEB) were calculated by the summation of sodium, potassium, calcium and magnesium. The 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 described by IITA (1984) was followed to obtain the ECEC. Base saturation was calculated by dividing the sum of TEB by the ECEC and was expressed in percentage (Black, 1965). Soil classification was done according to the USDA Soil Taxonomy (Soil Survey Staff, 2022). Fertility Capability Classification (FCC) classification system was carried out as developed by Buol, Sanchez and co-workers (Buol, 1972; Buol *et aI*, 1975, Sanchez *et aI,* 1982).

Data Presentation and Analysis

Data generated from the laboratory analysis of collected samples were organized in tables. Mean values were computed and analysis of variance (ANOVA) was used to test the relationship between and within means of the soil properties using statistical analysis system (SAS) computer application software.

Results and Discussion

Morphological characteristics of pedons

The morphological characteristics of the pedons of various districts are presented in Table 1. The altitude shows Chikila pedon has the highest elevation of 222m above sea level while Guyuk District pedon 1 has the lowest altitude with 180 m above sea level. The deepest profile pit was 170cm in depth at a location of 09°54.685’ North and 011°58.115’ at an altitude of 187m above sea level in Guyuk district, while the shallowest pedon was at an elevation of 222m and coordinate of 09°47.202’ North and 011°58.115’ East in Chikila district of the study area. The occurrence of these soils on a level to nearly level topography (0 – 2%) might have accounted for the depth of these soils: Faniran and Areola, (1978); Shafiu, (2000) and Voncir, (2002), -ended types to collect reliable data that slope is an important aspect in determining soil depth. Soil colour are mostly of 7.5YR and 10YR. These are predominantly high value and chroma indicating the soils to be well drained, similarly, Bundey and Westin (1965) reported that colour gradation is a good criterion for interpreting drainage conditions among soils. Few, fine and faint mottles were observed on the lower horizons in some of the pedons may be an indication of reduction process at lower depths (Ahmad, 1983; Brady and Weil, 2013).

Soil texture is dominantly sandy loam and sand in the pedons of Bobini and Guyuk districts while clayey in Chikila, Kola, Banjiram, Dumna and Kurnyi pedons (Table 1), the differnces in soil structure from north to south of the study area may be as a result of different parent materials found (Esu, 1999). Basalt and shale maybe responsible for the fine clayey soils in Chikila, Kola, Dumna, Banjiram and Kurniy districts. Sandstone is dominant in Guyuk and Bobini districts and maybe responsible for the sandy texture. Weak medium to coarse sub-angular blocky structure were observed throughout Bobini and Guyuk pedons, whereas the pedons of Chikila, Banjiram, Kurnyi, Kola, and Dumna were strong fine sub angular blocky except the lower horizons of Banjiram and Kurnyi pedons with strong platy structure. The consistency of the pedons in Bobini and Guyuk district were non-sticky when wet, loose to very friable when moist and soft when dry, the remaining district have pedons that are very sticky, very plastic when wet, firm to very firm when moist and hard to very hard when dry, Kparmwang (1993) reported that soils formed from basaltic parent material are generally sticky and plastic when wet and hard when dry. Few and fine (rff) roots were observed throughout the upper horizons. This could be the roots of crops and weed that were cultivated in the area. Similar characteristics were observed in morphological studies of some soils in Adamawa state, Nigeria, (Zata, 2006; Shobayo *et al.,* 2016; Saddiq *et al.,* 2016).

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Table 1. *Morphological characteristics of pedons*

Pedon	Coordinate	Altitude (m)	Depth (cm)	Colour Dry	Colour Moist	Mottles	Texture	Structure	Consistency	Inclusion
Bobini 1 Bodeno	N10º 00.42' E011º57.919'	206	0 – 24	7.5YR4/6	7.5YR4/3	N	LS	1msbk	Wns.np-ml-ds	rcm
			24 – 82	7.5YR7/1	7.5YR5/3	N	LS	1msbk	Wns.npl-ml-ds	rff
			82 – 110	7.5YR6/2	7.5YR6/4	n	L	2csbk	Wns.npl-ml-dl	n
			110 – 143	10YR6/8	10YR6/6	n	L	2csbk	Wns.npl-ml-dl	n
			143 – 150	7.5YR7/6	7.5YR5/8	n	SL	1csbk	Wns.npl-ml-ds	n
Bobini 2	N09º58.427' E011º55.622'	211	0 – 20	7.5YR5/6	7.5YR4/6	n	SL	1mabk	Wns.pl-mvf-ds	rfm
			20 -88	7.5YR7/1	7.5YR5/3	n	SL	1csbk	Wns.npl-ml-ds	rff
			88 – 110	7.5YR6/2	7.5YR6/4	n	SL	2csbk	Wns.npl-mvf-ds	n
			110 – 135	10YR6/8	10YR6/4	n	L	2csbk	Wns.npl-mvf-ds	n
			135 – 155	7.5YR6/6	7.5YR5/6	n	Sl	1csbk	Wns.npl-ml-dl	n
Guyuk 1 Rawe	N09º56.426' E011º50.92'	180	0 – 26	7.5YR4/3	7.5YR3/3	n	S	1csbk	Wns.npl-ml-dl	rcm
			26 – 71	7.5YR5/4	7.5YR4/4	n	SL	1msbk	Wns.npl-mvf-dl	n
			71 – 95	7.5YR3/3	7.5YR2.5/3	n	SL	1fsbk	Wns.npl-ms-ds	n
			95 – 151	7.5YR6/3	7.5YR5/6	n	S	1csbk	Wns.npl-ml-dl	n
Guyuk 2 Purakayo	N09º54.685' E011º58.115'	187	0 – 25	7.5YR4/4	7.5YR4/3	n	LS	1msbk	Wns.npl-mvf-ds	rff
			25 – 89	7.5YR7/1	7.5YR5/3	n	LS	1msbk	Wns.npl-ml-ds	n
			89 – 111	10YR4/6	10YR3/3	n	SL	1csbk	Wns.npl-ml-ds	n
			111 – 170	10YR6/2	10YR6/4	fff	S	1csbk	Wns.npl-ml-ml	n
Chikila	N09º47.202' E011º57.053'	222	0 – 29	10YR3/4	10YR2.5/1	n	C	3fsbk	wvpl-mvf-dvh	rff
			29 – 65	7.5YR2/3	7.5YR3/2	n	C	3fsbk	wvpl-mvf-dvh	n
			65 – 125	7.5YR3/3	7.5YR4/6	n	C	3fsbk	wvpl-mvf-dvh	n
Banjiram1 Tsohon Banjiram	N09º48.621' E011º57.756	207	0 – 22	7.5YR3/4	7.5YR3/3	n	C	3msbk	wsl.pl-mf-fh	rff
			22 – 96	7.5YR4/2	7.5YR3/2	n	C	3fsbk	wvp-mf-dvh	n
			96 – 120	10YR7/1	10YR7/6	n	SiC	3fsbk	wsl.pl-mf-dh	sfc
			120 – 145	10YR6//6	10YR5/6	fff	SiC	2fsbk	wsl.pl-mf-dh	scc
Banjiram Lokoro	N09º51.656' E011º57.150'	195	0 – 26	7.5YR4/4	7.5YR4/6	n	C	3csbk	wvs-mf-dvh	rcf
			26 – 92	7.5YR5/8	7.5YR8/8	n	SiC	3fsbk	wv.pl-mf-dvh	n
			92 – 141	7.5YR8/1	7.5YR6/1	n	SiC	2mpl	wv.s-mv.f-dh	Scc
Kola	N09º48.621' E011º57.756'	203	0 – 29	7.5YR3/2	7.5YR3/1	n	C	3csbk	wv.s-mf-dh	rff
			29 – 86	7.5YR4/6	7.5YR4/2	n	C	3fsbk	wv.pl-mvf-dv.h	n
			89 – 138	7.5YR8/1	7.5YR6/1	n	C	3fsbk	wv.pl-mvf-dv.h	n
Dumna	N09º39.543' E09º50.530'	198	0 – 28	7.5YR5/2	7.5YR4/1	n	C	3fsbk	wv.pl-mf-dv.h	rff
			28 – 98	7.5YR3/2	7.5YR2.5/3	n	C	3fsbk	wv.pl-mvf-dv.h	n
			98 – 153	7.5YR4/2	7.5YR3/1	n	C	3fsbk	wv.pl-mvf-dv.h	gfm
Kurnyi	N09º54.073' E011º53.373	220	0 – 25	7.5YR4/6	7.5YR5/6	n	C	3fsbk	wv.pl-mf-dv.h	rff
			25 – 80	7.5YR7/8	7.5YR6/8	n	C	3fsbk	wv.pl-mv.f-dv.h	n
			80 – 127	7.5YR8/1	7.5YR7/1	n	SiC	2fsbk	wv.pl-mv.f-dv.h	n
			127 – 148	7.5YR7/6	7.5YR6/6	n	SiC	3mpl	wv.pl-mf-dh	gfm

Mottles: n = none, fff = few fine and faint, fmd = few medium and distinct, cmd = common medium and distinct, ccd = common coarse and distinct.
Texture: S = sand, C = clay, Si = silt, L = loam.
Structure: 0 = structureless, 1 = weak, 2 = moderate, 3 = strong, f = fine, m = medium, c = coarse, sbk = subangular blocky, pl = platy.
Consistency: wns-ml-ds = wet non sticky-moist loose- dry soft, wns-mvf-ds = wet non sticky-moist very friable- dry soft, wvpl-mvf-dvh = wet very plastic-moist very firm-dry very hard, wsl.pl-mf-dh = wet slightly plastic-moist firm-dry hard.
Inclusion: r = roots, g = gravels, s = stones, f = few, c = common, m = many, f = fine, m = medium, c = coarse, rff = roots few and fine, gcc = gravel common and coarse, scm = stones common and medium.

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Physical properties of pedons and augered samples

The physical properties of the various pedons and augered samples in the districts are presented in Table 2 and 3.The particle size distribution range from 22 – 65% for sand, 12 – 33% for silt and 15 – 65% for clay, with pedons of Bobini and Guyuk having relatively higher proportion of sand to silt and clay while Chikila, Banjiram, Kola, Kurnyi and Dumna pedons have higher clay percentage than silt and sand in their horizons and augerd samples.

Table 2. *Physical properties of pedons*

Pedon	Depth	Sand (%)	Silt (%)	Clay (%)	Textural Class	Bulk Density (gcm^{-3})	Particle density (gcm^{-3})	Porosity (%)
Bobini1 (Bodeno)	0 – 24	66	20	13	SL	1.44	2.67	46
	24 – 82	65	18	16	SL	1.52	2.65	43
	82 – 110	60	16	23	L	1.53	2.67	43
	110 – 143	53	26	20	L	1.61	2.65	39
	143 – 150	68	16	15	SL	1.65	2.60	37
	Mean	62	19	17		1.55	2.65	42
Bobini 2 (Bobini)	0 – 20	64	14	21	L	1.39	2.65	48
	20 -88	61	15	23	L	1.48	2.69	45
	88 – 110	55	16	28	L	1.49	2.68	44
	110 – 135	52	22	25	CL	1.52	2.70	44
	135 – 155	66	19	14	SL	1.59	2.68	41
	Mean	60	17	22		1.49	2.68	44
Guyuk 1 (Rawe)	0 – 26	63	22	14	SL	1.40	2.57	46
	26 – 71	60	22	17	L	1.42	2.60	45
	71 – 95	65	20	14	SL	1.54	2.64	42
	95 – 151	68	14	17	SL	1.61	2.65	39
	Mean	64	20	16		1.49	2.61	43
Guyuk 2 (Purakayo)	0 – 25	70	15	14	SL	1.44	2.64	45
	25 – 89	61	22	16	L	1.48	2.60	43
	89 – 111	62	20	17	L	1.50	2.60	42
	111 – 170	65	20	14	SL	1.58	2.61	39
	Mean	65	19	15		1.50	2.61	42
Chikila	0 – 29	22	12	65	C	1.19	2.59	54
	29 – 65	25	10	64	C	1.20	2.50	52
	65 – 125	19	14	66	C	1.48	2.55	42
	Mean	22	12	65		1.29	2.55	49
Banjiram 1 (Tsohon-Banjiram)	0 – 22	23	30	46	C	1.03	2.64	61
	22 – 96	25	20	54	C	1.20	2.68	55
	96 – 120	19	31	49	C	1.26	2.61	52
	120 – 145	20	12	67	C	1.41	2.64	47
	Mean	22	23	54		1.23	2.64	54
Banjiram 2 (Lokoro)	0 – 26	20	31	48	C	1.15	2.63	56
	26 – 92	25	30	44	C	1.27	2.63	52
	92 – 141	27	29	43	C	1.27	2.60	51
	Mean	24	30	45		1.23	2.62	53
Kola	0 – 29	20	22	57	C	1.08	2.60	58
	29 – 86	22	8	69	C	1.37	2.65	48
	89 – 138	17	18	64	C	1.36	2.60	48
	Mean	20	16	63		1.27	2.62	51
Dumna	0 – 28	21	33	45	C	1.03	2.54	59
	28 – 98	24	35	40	CL	1.37	2.60	47
	98 – 153	22	30	47	C	1.48	2.60	43
	Mean	22	33	44		1.29	2.58	50
Kurnyi	0 – 25	30	10	59	C	1.14	2.61	56
	25 – 80	33	20	46	C	1.29	2.65	51
	80 – 127	35	35	29	CL	1.37	2.60	47
	127 – 148	33	30	36	CL	1.43	2.64	46
	Mean	33	24	43		1.31	2.63	50
	SEM	3.22	1.18	3.10		0.003	0.007	0.96
	CV (%)	46.90	35.06	54.83		11.90	1.61	12.69

S = sand, C = clay, Si = silt, L = Loam

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Thus, the pedons of Bobini and Guyuk district were sandy-loam to loam soils while the remaining district to the south of the study was clayey throughout (Table 2 and 3). This phenomenon can be attributed to the difference in type and nature of parent material found in the various district, Sandstone maybe responsible for the sandy texture of soil of Bobini and Guyuk district, while Basalt and shale could be reason for the clayey texture of soils to the south of the study area. Burton *et'al.,* (1980) reported that soils typically inherit a great deal of structure and minerals from their parent materials, and as such are often classified based on their content of consolidated or unconsolidated mineral materials that has undergone some degree of physical or chemical weathering and the mode by which the materials were most recent transported. Results are similar to findings of Jahknwa *et'al.,* (2015) on some spatial variation in some physical properties, conducted in some soils of Guyuk area of Adamawa state.

Mean Bulk density and particle density values of pedons in Bobini and Guyuk ranged from 1.49 to 1.55g/cm^3 and 2.61 to 2.68g/cm^3 respectively. Lower bulk density values were recorded in all the surface horizons of (Table 2) and surface augered samples (Table 3), thus bulk increases with increase in depth, Cressweil and Hamilton, (2002) reported that bulk density increase with compaction at depth and very compacted subsoil or strongly indurated horizons may exceed 2.0g/kg.

There was no significant difference in the results obtained for particle density both in the augered samples (Table 3) and the samples obtained from the profile pit (Table 2),

Table 3. *Means of soil physical properties of augered samples*

District	%Sand Depth (cm)		%Silt Depth(cm)		%Clay Depth (cm)		Textural class Depth (cm)		BD (g/cm^3) Depth (cm)		PD (g/cm^3) Depth (cm)		Porosity (%) Depth (cm)	
	0–20	20 -50	0 – 20	20 50	0–20	20 -50	0–20	20 50	0–20	20-50	0–20	20-50	0–20	20 50
bini	74.60^c	66.40^d	11.20a	16.20^a	13.20^a	16.40^a	SL	SL	1.49^c	1.53^b	2.66^d	2.68a	43.80^a	43.20^a
Guyuk	72.80^c	68.20^d	11.60a	14.20^a	14.40^a	16.40^a	SL	SCL	1.45^{bc}	1.48^b	2.64^{cd}	2.63a	44.80^a	43.80^a
Kurnyi	22.80^{ab}	32.40^c	16.00a	25.40^b	60.20^b	41.20^b	C	C	1.20^a	1.23^a	2.62^{bcd}	2.69a	54.00^{bc}	54.20^b
Banjiram	21.80^{ab}	29.00^{bc}	13.00a	14.80^a	44.20^b	55.20^c	C	C	1.18^a	1.27^a	2.57^{bc}	2.81a	54.00^{bc}	54.20^b
Chikila	18.40^a	17.00^a	15.20a	20.00^{ab}	65.40^b	62.00^c	C	C	1.27^{ab}	1.21^a	2.48^a	2.61a	48.60^{ab}	53.40^b
Kola	20.80^{ab}	17.60^a	17.60a	16.40^{ab}	60.60^b	60.20^c	C	C	1.10^a	1.20^a	2.56^a	2.60a	57.20^c	53.40^b
Dumna	27.80^b	22.40^{ab}	10.80a	16.00^a	60.40^b	60.60^c	C	C	1.16^a	1.26^a	2.58^{bc}	2.60a	55.20^{bc}	51.40^b
SEM	4.07	3.55	0.69	0.93	3.83	3.49			0.03	0.02	0.01	0.03	1.04	1.00
CV (%)	65.01	58.10	30.05	31.36	46.92	45.65			13.05	10.92	2.55	6.43	12.02	11.35

Means with same letter(s) in the same column are not significantly different at $p < 0.05$
BD = bulk density, PD = particle density. S = sand, C = clay, Si = silt, L = Loam

Thien and Graveel, (2002) reported that particle density vary little between minerals and has little practical significance except in the calculation of porosity.

Percentage porosity has a mean range of 42% to 61%, it showed porosity to pedons of Bobini and Guyuk district having lower values than the remaining pedons in the study area and it further shows in table 4 that percentage porosity was lower in augerd samples of Bobini and Guyuk district with Bobini having the least mean of 43.80 and 43.20 both on surface and subsurface as compared to porosities of Chikila, Banjiram, Kola, Dumna and Kurnyi which have higher mean values, this is possible because the different types of soil structure found in the various districts, the district to the south (Bobini and Guyuk) are basically sandy while the remaining are deep clay soils, Hunt and Gikes, (1992) reported acritical values of bulk density for restricting root growth varies with soil type. Similarly, Stan, (2016) reported that sandy soils usually have higher bulk density (1.3 to 1.7g/kg) than fine silt and clay with 1.1 to 1.6g/kg, because they have larger but fewer pore spaces but clay sized materials have higher porosity because of surface tension capillarity and crystal structure.

Chemical properties of pedons and augered samples of the study area

Table 4a, 4b , 5, 6 and 7 shows the chemical properties of pedons and augered samples of the study area: pH ranged from 6.23 to 7.6 with the least value in pedon 1 of Guyuk district and Dumna pedon has the highest value, whereas, pH values in Table 4 ranged from 6.18 to 7.62, Kurnyi district at the sub-

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surface level has the highest value while Guyuk district with the least at the 20 to 50 depth, this entails.
Soils of Bobini and Guyuk district to be slightly acidic while Chikila, Banjiram, Kola, Dunmna and Kurnyi are slightly alkaine, Hodges, (2010) reported that pH value near neutral (i.e slightly acidic or alkaline) have optimum conditions for the release of plant nutrients and use for plant growth and development.

Table 4a. *Soil chemical properties of pedons*

District	Depth (cm)	pH	EC (ds/m)	C org (%)	TN (g/kg)	C:N Ratio	AV-P (Mg/kg)	PBS (%)
Bobini1 Bodeno	0 – 24	6.2	0.05	1.27	0.11	11.52	10.45	90.62
	24 – 80	6.5	0.06	1.25	0.12	10.42	10.23	92.03
	80 – 110	6.4	0.06	1.25	0.13	9.59	9.80	89.04
	110 – 140	6.2	0.11	0.80	0.12	6.65	9.16	87.57
	140 – 150	6.5	0.16	1.23	0.14	8.76	8.30	90.22
	Mean	6.33	0.07	1.14	0.12	9.55	9.91	89.82
Bobini 2 Bobini	0 – 20	6.2	0.10	1.28	0.13	9.85	10.00	90.57
	20 -88	6.3	0.13	1.30	0.12	10.83	10.01	90.49
	80 – 100	6.3	0.15	1.42	0.14	10.14	9.55	91.14
	110 – 135	6.4	0.18	1.00	0.14	7.14	9.00	90.85
	130 – 155	6.8	0.93	1.00	0.11	9.09	9.50	89.16
	Mean	6.3	0.14	1.25	0.13	9.41	9.64	90.76
Guyuk 1 Rawe	0 – 36	6.3	0.04	1.25	0.11	11.34	11.52	90.82
	36 – 71	5.8	0.20	0.91	0.14	6.48	9.80	94.05
	71 – 95	6.1	0.19	0.98	0.15	6.52	9.24	90.07
	95 – 151	6.7	0.04	0.75	0.09	8.50	9.02	96.14
	Mean	6.23	0.12	0.97	0.12	8.21	9.90	92.77
Guyuk 2 Purakayo	0 – 25	6.7	0.09	1.55	0.15	10.33	10.22	94.14
	25 – 89	6.5	0.12	1.56	0.13	12.00	10.15	92.66
	89 – 111	6.3	0.22	1.84	0.15	12.27	9.00	93.05
	111 – 140	6.4	0.08	1.55	0.12	12.92	7.59	92.20
	Mean	6.48	0.13	1.63	0.14	11.88	9.24	93.01
Chikila	0 – 30	7.3	0.18	1.24	0.15	8.25	10.02	91.80
	30 – 65	7.3	0.18	1.26	0.15	8.38	11.52	92.34
	65 – 125	7.5	0.12	1.13	0.18	6.28	9.37	90.80
	Mean	7.37	0.16	1.21	0.16	7.64	10.30	91.65
Banjiram 1 Tsohon-Banjiram	0 – 22	6.9	0.42	1.89	0.19	9.95	11.11	93.69
	22 – 96	7.2	0.19	1.76	0.15	11.73	10.34	94.64
	96 – 120	7.1	0.2	0.70	0.10	7.00	10.03	95.04
	120 – 145	7.3	0.21	0.54	0.09	6.50	9.66	92.99
	Mean	7.13	0.26	1.22	0.13	8.80	10.29	94.09
Banjiram 2 Lokoro	0 – 32	6.3	0.21	1.26	0.15	8.38	9.37	93.52
	32 – 112	7.5	2.65	1.06	0.12	8.81	9.16	94.30
	112 – 141	7.1	2.28	1.00	0.12	8.33	8.73	93.41
	Mean	6.97	1.71	1.11	0.13	8.51	9.09	93.74
Kola	0 – 29	7.0	0.18	2.18	0.20	10.90	10.66	94.57
	29 – 86	7.4	0.46	1.21	0.15	8.06	9.16	94.49
	89 – 138	7.3	0.60	1.10	0.13	8.44	8.73	91.42
	Mean	7.23	0.41	1.5	0.16	9.13	9.52	93.49
Dumna	0 – 28	7.5	0.08	1.57	0.13	12.07	8.94	93.01
	28 – 98	7.6	0.08	1.36	0.15	9.04	9.37	92.04
	98 – 153	7.7	0.24	1.16	0.13	8.90	9.16	89.58
	Mean	7.6	0.13	1.36	0.14	10.00	9.16	91.54
Kurnyi	0 – 35	7.1	0.17	1.48	0.14	10.55	8.73	96.80
	35 – 80	7.2	0.85	1.31	0.13	10.07	9.59	95.24
	80 – 127	7.6	0.48	1.35	0.14	9.62	8.73	98.45
	127 – 148	7.8	1.59	1.00	0.13	7.67	9.59	98.84
	Mean	7.43	0.77	1.29	0.14	9.48	9.16	97.33
	SEM	0.09	0.09	0.06	0.003	0.44	0.13	0.41
	CV (%)	7.78	55.35	29.38	17.29	28.31	8.61	2.73

EC = electric conductivity, org, C= organic carbon, TN = total nitrogen, C:N = carbon to nitrogen ratio, Av. P = available phosphorus, PBS = percentage base saturation.

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Table 4b. *Soil chemical properties of pedons*

District	Depth	Ca	Mg	Ca:Mg	Na	K	TEB	H	Al	TEA	ECEC	ESP
	(cm)	(cmol/kg)										
	0 – 24	15.53	7.32	2.12	0.17	0.18	23.20	1.0	1.4	2.4	25.60	0.68
	24 – 80	17.50	9.69	1.81	0.22	0.31	27.72	1.1	1.3	2.4	30.12	0.72
Bobini1	80 – 110	13.16	8.97	1.47	0.26	0.36	22.75	0.9	1.9	2.8	25.55	1.02
Bodeno	110 – 140	18.29	8.05	2.27	0.17	0.26	26.77	1.6	2.2	3.8	30.57	0.57
	140 – 150	15.92	10.34	1.54	0.26	0.23	26.76	1.0	1.9	2.9	29.66	0.88
	Mean	16.12	8.51	1.92	0.21	0.28	25.11	1.2	1.7	2.9	27.96	0.75
	0 – 20	17.70	6.00	2.95	0.13	0.19	24.02	1.0	1.5	2.5	26.52	0.49
	20 -88	15.00	7.20	2.08	0.13	0.50	22.83	0.9	1.5	2.4	25.23	0.52
Bobini 2	80 – 100	21.00	5.30	3.96	0.20	0.23	26.73	1.1	1.5	2.6	29.33	0.68
Bobini	110 – 135	18.90	3.50	5.40	0.11	0.34	22.85	1.2	1.1	2.3	25.15	0.44
	130 – 155	17.50	3.30	5.30	0.22	0.36	21.38	0.8	1.8	2.6	23.98	0.92
	Mean	18.15	5.50	3.6	0.14	0.32	24.11	1.1	1.4	2.5	26.60	0.53
	0 – 36	20.50	10.85	1.89	0.09	0.23	31.67	1.1	2.1	3.2	34.87	0.25
Guyuk 1	36 – 71	26.71	10.79	2.48	0.26	0.15	37.91	0.6	1.8	2.4	40.31	0.65
Rawe	71 – 95	23.16	10.97	2.11	0.17	0.18	34.48	1.7	2.1	3.8	38.28	0.45
	95 – 151	26.71	12.83	2.08	0.22	0.10	39.86	0.6	1.0	1.6	41.46	0.52
	Mean	24.27	11.36	2.14	0.19	0.17	35.98	1.0	1.8	2.8	38.73	0.47
	0 – 25	26.45	10.24	2.58	0.10	0.19	36.98	1.0	1.3	2.3	39.28	0.25
Guyuk 2	25 – 89	21.10	10.00	2.11	0.13	0.32	31.55	0.9	1.6	2.5	34.05	0.38
Purakayo	89 – 111	24.25	9.99	2.43	0.22	0.37	34.83	0.9	1.7	2.6	37.43	0.59
	111 – 140	20.00	9.05	2.21	0.25	0.27	29.57	1.0	1.5	2.5	32.07	0.78
	Mean	22.95	9.82	2.33	0.18	0.29	33.23	0.9	1.5	2.5	35.71	0.50
	0 – 30	20.25	10.57	1.92	0.09	0.44	31.34	1.1	1.3	2.8	34.14	0.25
Chikila	30 – 65	18.02	10.03	1.80	0.30	0.59	28.94	1.3	1.1	2.4	31.34	0.97
	65 – 125	15.50	7.55	2.05	0.22	0.41	23.68	1.1	1.3	2.4	26.08	0.83
	Mean	17.92	9.38	1.92	0.20	0.48	27.99	1.2	1.2	2.5	30.52	0.68
	0 – 22	32.55	10.00	3.26	0.17	0.36	43.08	1.0	1.9	2.9	45.98	0.38
Banjiram 1	22 – 96	33.53	10.10	3.32	0.26	0.23	44.12	0.9	1.6	2.5	46.62	0.56
Tsohon-	96 – 120	35.90	9.85	3.64	0.13	0.15	46.03	0.7	1.7	2.4	48.43	0.27
Banjiram	120 – 145	25.20	9.00	2.80	0.13	0.18	34.51	1.2	1.4	2.6	37.11	0.35
	Mean	31.8	9.74	3.26	0.17	0.23	41.94	0.9	1.7	2.6	44.54	0.39
	0 – 32	30.54	11.18	2.73	0.61	0.74	34.62	1.1	1.3	2.4	37.02	1.64
Banjiram 2	32 – 112	31.77	16.90	1.88	0.52	0.54	34.71	1.0	1.1	2.1	36.81	1.36
Lokoro	112 – 141	17.25	10.00	1.73	0.70	0.38	28.33	0.5	1.5	2.0	30.33	2.17
	Mean	26.52	12.69	2.11	0.61	0.55	32.55	0.9	1.3	2.2	34.72	1.72
	0 – 29	29.24	14.59	2.00	0.91	0.56	45.31	1.1	1.5	2.6	47.91	1.91
Kola	29 – 86	22.78	10.90	2.09	0.13	0.51	34.32	0.8	1.2	2.0	36.32	0.36
	89 – 138	17.11	7.76	2.20	0.26	0.44	25.57	0.8	1.6	2.4	27.97	0.93
	Mean	23.04	11.08	2.10	0.43	0.50	35.07	0.9	1.4	2.3	37.40	1.07
	0 – 28	17.50	8.50	2.06	0.30	0.31	26.61	0.9	1.1	2.0	28.61	1.06
Dumna	28 – 98	15.40	8.00	1.93	0.22	0.67	24.28	0.8	1.3	2.1	26.38	0.82
	98 – 153	15.25	6.45	2.36	0.17	0.49	22.36	1.1	1.5	2.6	24.96	0.70
	Mean	16.05	7.65	2.12	0.23	0.49	24.42	0.9	1.3	2.2	26.65	0.86
	0 – 35	45.45	20.10	2.26	0.30	0.77	66.62	1.0	1.2	2.2	68.82	0.43
	35 – 80	26.90	12.60	2.13	0.22	0.36	40.08	0.9	1.1	2.0	42.08	0.50
Kurnyi	80 – 127	48.60	20.58	2.36	0.74	0.23	70.15	0.2	0.9	1.1	71.25	1.01
	127 – 148	35.00	15.66	2.23	0.35	0.23	51.24	0.1	0.5	0.6	51.84	0.65
	Mean	38.99	17.24	2.25	0.40	0.40	57.02	0.6	0.9	1.5	58.50	0.65
	SEM	1.36	0.60	0.14	0.03	0.03	1.83	0.05	0.06	0.09	1.79	0.07
	CV (%)	35.79	36.70	35.55	71.26	47.76	33.60	31.69	24.63	23.70	30.70	59.63

TEB = total exchangeable bases, TEA = Total exchangeable acidity, ECEC = effective cation exchange capacity, EPS, exchangeable sodium percentage.

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Similar results were recorded by Shehu *et'al.,* (2015) in a study of fertility status in some selected soils in the sudan savanna biome of the Northern Nigeria. Electric conductivity (EC) ranged from 0.07ds/m in pedon1 of Bobini ditrict to1.71ds/m in pedon of Banjiram district, while it showed no significant difference between surface layers of Bobini, Kurnyi, Banjiram, Kola and Dumna districts at $p < 0.05$, with higher values than that of Guyuk district which has a mean value of 0.064ds/m and lower than Chikila district with mean 0.242ds/m, same trait was observed at the subsurface level. Thus, there was no problem of salinity as EC is generally below 4dS/m. Brady and Weil, (2013) reported a critical value of 4dS/m, above which can adversely affect plant growth. Organic carbon (OC) and total nitrogen (TN) ranged from 0.97% and 0.12g/kg to 1.63% and 0.16g/kg .Pedons, pedon 1 of Guyuk district has the least value both in OC and TN, whereas, Carbon to nitrogen ratio was highest in pedon 2 of Guyuk district with a value of 11.88 ≈ 12:1 carbon to nitrogen ratio and the least value was recorded in chikila pedon and has a value of 7.64 ≈ 8:1 ratio of carbon to nitrogen. Available phosphorus has a mean

Table 5. *Means of chemical properties of augered samples*

District	pH 1:2		EC (ds/m)		Org. C (%)		TN (%)		C:N		Av. P (mg/kg)	
	Depth (cm)		Depth (cm)		Depth (cm)		Depth (cm)		Depth (cm)		Depth (cm)	
	0 –20	20 50	0 – 20	20 50	0 -20	20-50	0 – 20	20 50	0 – 20	20 50	0 - 20	20 50
Bobini	6.62^{ab}	6.52^{ab}	0.094^{ab}	0.100^{a}	1.00a	1.18a	0.10a	0.19a	9.50a	10.0a	10.75a	10.79a
Guyuk	6.28^{a}	6.18^{a}	0.064^{a}	0.032^{a}	0.98a	1.19a	0.12a	0.09a	8.24a	12.83a	11.48a	10.66a
Kurnyi	7.32^{bc}	7.62^{c}	0.110^{ab}	0.148^{ab}	1.20a	1.03a	0.13a	0.12a	9.48a	10.79a	10.83a	10.01a
Banjiram	7.38^{bc}	7.46^{bc}	0.198^{ab}	0.226a^{b}	1.33a	1.36a	0.14a	0.13a	9.84a	10.42a	10.49a	9.72a
Chikila	7.28^{bc}	7.40^{bc}	0.242^{b}	0.952^{b}	1.20a	1.32a	0.13a	0.12a	9.12a	11.72a	10.45a	10.45a
Kola	7.52^{c}	7.34^{bc}	0.144^{ab}	0.284^{ab}	1.33a	1.32a	0.13a	0.13a	10.25a	10.16a	11.24a	11.69a
Dumna	7.42^{c}	7.34^{bc}	0.140^{ab}	0.110^{a}	1.30a	1.43a	0.14	0.13a	9.89a	10.96a	11.04a	10.38a
SEM	0.10	0.11	0.02	0.08	0.04	0.04	0.01a	0.01	0.28	0.37	0.23	0.25
CV (%)	8.04	9.42	62.71	79.18	21.76	19.31	18.81	19.64	17.30	19.94	12.45	13.81

Means with same letter(s) in the same column are not significantly different at $p < 0.05$ - EC = electric conductivity - org, C= organic carbon, TN = total nitrogen, C:N = carbon to nitrogen ratio, Av. P = available phosphorus.

Table 6. *Means of exchangeable bases*

District	Ca^{++}		Mg^{++}		Ca:Mg		Na^{+}		K^{+}	
	(Cmol/kg)									
	Depth (cm)		Depth(cm)		Depth (cm)		Depth (cm)		Depth (cm)	
	0 – 20	20 - 50	0 – 20	20 - 50	0 – 20	20 - 50	0 – 20	20 - 50	0 – 20	20 - 50
Bobini	14.86^{a}	13.67^{a}	7.21^{a}	3.86^{a}	2.17^{ab}	3.44^{cb}	0.16^{a}	0.22a	0.10^{a}	0.21^{a}
Guyuk	16.72^{ab}	13.54^{a}	9.25^{ab}	6.59^{b}	1.83^{a}	2.10^{ab}	0.11^{a}	0.14a	0.25^{ab}	0.26^{a}
Kurnyi	39.55^{c}	38.73^{b}	11.55^{b}	11.39^{c}	3.44^{b}	3.41^{bc}	0.26^{a}	0.43a	0.38^{abc}	0.41^{ab}
Banjiram	40.06c	41.36^{b}	11.54^{b}	10.74^{c}	3.48^{b}	3.90^{c}	0.19^{a}	0.36a	0.75^{d}	0.60^{b}
Chikila	29.95^{bc}	26.76^{ab}	10.87^{ab}	11.18^{c}	2.80^{ab}	2.41^{ab}	0.63^{b}	0.34a	0.60^{cd}	0.58^{b}
Kola	22.40^{ab}	19.36^{a}	11.29^{b}	11.44^{c}	2.04^{a}	1.72^{a}	0.32^{a}	0.52a	0.70^{cd}	0.61^{b}
Dumna	23.46^{ab}	19.98^{a}	12.23^{b}	11.47^{c}	1.97^{a}	1.74^{a}	0.15^{a}	0.21a	0.57^{bcd}	0.60^{b}
SEM	1.91	2.15	0.40	0.52	0.15	0.18	0.06	0.04	0.42	0.03
CV (%)	42.34	51.28	42.11	42.47	35.32	40.23	81.24	74.86	50.97	43.04

Means with same letter(s) in the same column are not significantly different at $p < 0.05$

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Table 7. *Means of total exchangeable bases, Hydrogen, Aluminum, total exchangeable acidity, effective cation exchange capacity, percentage base saturation and exchangeable sodium percentage*

District	TEB		H^+		Al^{+++}		TEA		ECEC		PBS		ESP	
	(cmol/kg)										(%)			
	Depth (cm)		Depth(cm)		Depth (cm)		Depth (cm)		Depth (cm)		Depth (cm)		Depth (cm)	
	0 – 20	20 -50	0 – 20	20-50	0 –20	20-50	0–20	20-50	0–20	20-50	0-20	20-50	0-20	20-50
Bobini	22.43^{a}	17.95^{a}	1.60^{a}	1.10^{a}	2.30^{a}	1.66^{a}	3.90^{a}	2.76^{a}	24.59^{a}	20.71^{a}	91.41^{ab}	85.50^{a}	0.83^{ab}	0.66^{a}
Guyuk	26.35^{a}	20.54^{a}	1.52^{a}	1.34^{a}	2.14^{a}	1.90^{a}	3.66^{a}	3.24^{a}	30.01^{a}	23.78^{a}	87.48^{a}	86.25^{ab}	0.40^{a}	0.71^{a}
Kurnyi	51.74^{c}	50.95^{c}	0.86^{a}	1.14^{a}	1.30^{a}	1.62^{a}	2.16^{a}	2.76^{a}	55.63^{c}	53.72^{c}	93.06^{b}	94.70^{c}	0.50^{ab}	0.82^{a}
Banjiram	52.54^{c}	53.06^{c}	1.12^{a}	1.64^{a}	1.70^{a}	1.84^{a}	2.82^{a}	3.48^{a}	55.64^{c}	56.55^{c}	94.90^{b}	93.61^{c}	0.35^{a}	0.77^{a}
Chikila	42.05^{bc}	38.87^{bc}	1.52^{a}	1.28^{a}	1.96^{a}	1.76^{a}	3.48^{a}	3.04^{a}	45.53^{bc}	41.96^{bc}	92.02^{ab}	92.38^{bc}	1.46^{b}	0.89^{a}
Kola	34.71^{ab}	31.94^{ab}	1.10^{a}	1.34^{a}	1.56^{a}	1.42^{a}	2.66^{a}	2.76^{a}	37.36^{ab}	35.28^{ab}	92.82^{b}	90.61^{bc}	0.88^{ab}	1.61^{a}
Dumna	36.42^{ab}	32.27^{ab}	1.28^{a}	1.20^{a}	1.58^{a}	1.44^{a}	2.86^{a}	2.64^{a}	39.28^{ab}	34.91^{ab}	92.64^{b}	92.60^{bc}	0.42^{a}	0.66^{a}
SEM	2.14	2.48	0.08	0.07	0.10	0.09	0.17	0.14	2.20	2.50	0.53	0.74	0.10	0.14
CV (%)	33.27	41.77	37.64	31.56	31.91	31.25	32.54	28.51	31.68	38.84	3.39	4.82	86.02	87.80

Means with same letter(s) in the same column are not significantly different at $p < 0.05$ - TEB = total exchangeable bases, TEA = Total exchangeable acidity, ECEC = effective cation exchange capacity, PBS = percentage base saturation, EPS=exchangeable sodium percentage.

ranged from 9.09mg/kg in pedon 2 of Banjiram district to 10.30mg/kg in Chikila pedon whereas, in Table5, shows no significant difference in values of organic carbon, total nitrogen, carbon to nitrogen ratio and available phosphorus at $p < 0.05$ level of significance. OC and TN were generally low throughout the study area, Beernaert and Bitondo, (1992) reported a critical value of 1 -2% for OC and 0.5 to 1.25g/kg for TN. The low level of OC may be attributed to removal of crop residue from the farmlands as observed in the study area while low TN reflects the low value of OC in the study area. Results obtained for OC and TN agrees with the findings of Raji and Mohammed, (2000) who reported that 80% of the soil samples in Nigerian savanna soils contain less than 1% organic carbon while only 20% greater than 1% OC in localized sampled areas. The values of soil available phosphorus were generally medium 5 to 15mg (Beernaert and Bitondo, 1992), and its concentration was observed to decrease with depth both in the pedons and augered samples in all the districts, Hodges (2010) reported that phosphorus is not easily leached from the soil because of its strong bond to the soil particles therefore it decreases in concentration with subsequent increase in depth.

Exchangeable bases in Table 4, shows: calcium (Ca), magnesium (Mg), sodium (Na) and potassium (K), have their least mean values of 16.05cmol/kg, 8.51cmol/kg, 0.14cmol/kg and 0.17 cmol/kg respectively calcium and magnesium was most in Kurnyi and Banjiram pedons with Kurnyi pedon having the highest mean value of 38.99cmol/kg and 17.24cmol/kg, while there was no significant difference in the mean values of sodium and potassium throughout the pedons of the study area. Guyuk, Kola and Dumna ditrict which do not vary significantly at $p < 0.05$, with Bobini district showing least mean value of 13.67cmol/kg and Banjiram district having the highest mean value of 41.36cmol/kg at the 20 to 50 layer for calcium, magnesium has a mean range of 3.86 to 12.23cmol/kg with higher values found in both at the surface and subsurface of Dumna district, there was no significant difference in value obtained for sodium at both surface and subsurface soils, potassium shows variation between all districts at the 0 to 20cm level, with Bobini having the least value of 0.10cmol/kg and the most value was gotten from the soils of Banjiram district, the was no significant difference between Bobini and Guyuk district in values of K at the subsurface layer having lower values of 0.21 and 0.26 respectively at $p < 0.05$, and higher values in Banjiram and Dumna districts. Calcium and Magnesium was observed to be very high in all of the districts, this is attributed to the

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nature of parent materials found within the study area which are calcic in nature and transported throughout the study area, Wikipedia (2016) stated that Guyuk Local Government has a lot of limestone Deposits. Hodges, (2010) reported that limestone and dolomite contains 21 – 30% calcium, 6 to 12% magnesium and 0.03% sulphur. Similar results were recorded by Zata, (2006) in a research conducted at Savanna Sugar Company, Adamawa state. K and Na are generally low given critical rating by Beernaert and Bitondo, (1992) and results were obtained were also similar to findings of Jamala *et'al.,* (2012) in the evaluation of fertility status of some fadama soils in Adamawa state.

Total exchangeable bases (TEB) inTable 4 shows higher values in pedon Kurnyi and pedon 1 of Banjiram district with mean values of 57.02cmol/kg, 41.9cmol/kg respectively, while Bobini pedon 2 has the lowest mean value of 24.11cmol/kg, Total exchangeable acidity (TEA) shows no significant difference throughout the pedons of the study area with range of 1.5cmol/kg to 2.8cmol/kg, while in Table 7, TEB ranged from 22.43 to 52.54cmol/kg at the surface 0 – 20cm layer and 17.95 to 53.06cmol/ at the 20 – 50cm layer, it further showed Bobini and Guyuk district with lower values and are not significantly different as to Kurnyi and Banjiram with higher values at $p < 0.05$ level of significance. There is no significant difference in the values obtained for H, Al, and TEB throughout the districts at $p < 0.05$. TEA values are generally rated low (kwparmwang *et'al.,* 1998; Usman 2005)

Effective cation exchange capacity (ECEC) in Table 4 was higher in Kurnyi pedon with a mean value of 58.50cmol/kg and least in pedon 2 of Bobini district with mean of 26.60cmol/kg, there was no significant difference in results obtained exchangeable sodium percentage (ESP). Percentage base saturation (PBS) gave higher percentage in kurnyi pedon with 97% and lowest was recorded in pedon 1 of Bobini district with mean value of 89%. While, the augered samples in table 7 shows, ECEC both at surface and subsurface layer has a range of 24.59 to 55.64cmol/kg and 20.71 to 56.55cmol/kg respectively, with lowest mean value in Bobini and highest mean in Banjiram district. PBS ranged on the surface layer from 87.40 to 94.90%, Guyuk and Banjiram have the lowers and highest means, while at the subsurface it ranged from 85.50% in Bobini to 93.61% in Banjiram district of the study area. EPS showed no significant difference in results obtained from Guyuk, Banjiram, and Dumna district which have lower values than that of Chikila, while at the subsurface layer there is no significant difference in results obtained for EPS throughout all the districts at 5% level of significance. Soil texture could be the reason for the variation in ECEC values in the south of the study area are dominantly sandy (Bobini and Guyuk districts) which have lesser exchangeable site and can hold less ions than the clayey textured soils to the north, Bohn, *et al.,*(2001) reported that clay sized particles have more surface area to volume ratio and can hold more ion than coarse sized particles in the soil solid phase, therefore responsible for bulk of the chemistry in soils. Results obtained in Chikila, Banjiram, Kola, Dumna and Kurnyi districts are similar to finding of (Zata *et al.,* 2013) on characterization of some Usterts in Northeastern Nigeria. There was no problem of sodicity throughout all the soils of the study area as ESP was rated low (Kparmwang, *et al.,* 1998), similar results were recorded in various researches conducted within Adamawa State (Saddiq *et al.,* 2016, Jamala, *et al.,* 2012)

Soil variability

Variability of soil properties is indicated by the coefficient of variability (CV) in percentage in various Tables. Coefficient of variation values according to Tabi and Ogunkunle (2007), that has values ranging from 0-15% are considered least variable, 15-35% moderately variable and >35% are highly variable, it also shows percentage variability in various soil properties as it relates to increase in depth in all the pedons of the study.

Physical properties of pedons in Table 2, showed high variability in results obtained for percentage sand, %silt and %clay both within and between pedons, with CV values of 46.9, 35.0 and 54.8% respectively, this may be due to the clear distinction between texture of districts as seen from north to south of the study area which arise as a result of differences in geology and parent material the originate from (Brady and weil, 2013). Furthermore, moderate variability exist between and within pedons in values of bulk density and porosity with CV values of 11.9% and 12.69% respectively, while particle density has a low variable value of 1.61, low variable value that exist between and within pedons in particle density may be as a result of little variation of particle density in all soil except organic soil (Thien and Graveel, 2002). Variation in physical properties

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of augered samples showed high variability in percentage sand and percentage clay both at surface and subsurface depth, moderate variation in values of percentage silt while values of each of bulk density, particle density and porosity showed low variability both within and between districts in all the area of study.

Chemical properties as seen on table 4, 5, 6 and 7 showed highly variable values in EC, Ca, Mg, K, and ESP, moderate variability was obtained in each of OC, TN, H, Al, TEB, TEA and ECEC while low variability was obtained in values of pH, avil. P, and PBS in all the soils of the study area.

Soil classification

The soil classification of the study is presented in Table 8. According to USDA Soil Taxonomy (Soil Survey Staff, 2022), the soils of Bobini and Guyuk districts are of the order Alfisols because they have more than 35% base saturation meaning calcium, magnesium and potassium are relatively abundant, moderate leaching of clay leading to the formation of kandic horizon, the Alfisols are of the aridic moisture regime- dry moisture conditions of the soil up to 90 consecutive days, and the soils are basically sandy textured throughout all its horizons, Guyuk pedons have petrocalcic horizon and are referred to as *Calcic Psammustalfs,* while those of Bobini are regarded as *Typic Psammusalfs*, "typic" is used for the subgroup that is thought to typify the central concept of a great group.

The soils of Kurnyi and Banjiram districts are referred to as *Calcic Haplusterts* because of the presence of a petrocalcic diagnostic horizon while those of Chikila, Kola, and Dumna districts are *Typic Haplusterts* this is because of the soils have a deep wide crack on drying and swell appreciably on wetting, the clay content of the soils was more than 35% throughout the pedon depth with some slickness on the ped surface, gilgai micro-relief was observed, the moisture regime is ustic moisture regime and the was minimum horizons development throughout all the pedons of these district.

According to the FCC system, presented in Table 8, the soils of Bobini and Guyuk districts have sandy top and subsoils, they are low in organic carbon and have dry moisture content of up to 90 consecutive days, and are presented as "S dm" while the soils of Kurnyi, Banjiram, Chikila, Kola and Dumna districts have clayey top and subsurface structure, swelling and shrinking on wetting and drying clay type, high level of phosphorus fixation belonging to fertility class "C div". Furthermore, the soils of Kurnyi and Banjiram also have free calcium carbonate and pH higher than 7.3 and belong to the fertility class "C divb".

Table 8. *Summary of the FCC and USDA nomenclature*

District	FCC	USDA nomenclature
Bobini	S dm	Typic Psammustalfs
Guyuk	S dm	Calcic Psammustalfs
Kurnyi	C divb	Calcic Haplusterts
Banjiram	C divb	Calcic Haplusterts
Chikila	C div	Typic Haplusterts
Kola	C div	Typic Haplusterts
Dumna	C div	Typic Haplusterts

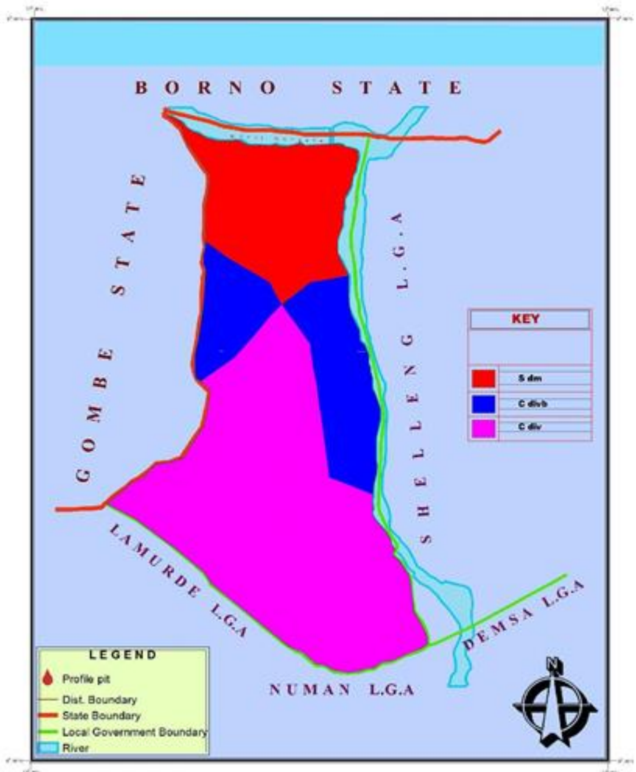

Figure 2. *Soil fertility map of Guyuk local government area*

Conclusions

In conclusion, profile pits were sunk and morphological properties of the pedons were observed, soils of the study area were collected and analyzed for physico-chemical properties in the laboratory using standard laboratory procedures,

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results were further analyzes using the SAS computer statistical package, the soils of the study area generally have good potentials for smooth growth and development of crops, this can be seen through high values of ECEC – the ability to hold and retain plant nutrient, non-saline nature of soils, good sub angular structure and normal critical values of bulk density that permits and allows easier roots penetration in the soils. Although, some limitations do exist according to the fertility capability classification (FCC), these are; the possibility of phosphorus fixation by high clay content of some soils of the study area and the general dry moisture conditions of the soils - up to 90 consecutive days of dry conditions, these limitations can be checkmate through integrated nutrient management system (INM system) and irrigation for better crop production and sustainable agricultural production.

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