CHARACTERIZATION, CLASSIFICATION AND MANAGEMENT OF SELECTED SOILS IN SOUTHERN GUINEA SAVANNA AREA OF NIGER STATE.

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ABSTRACT
There is need to provide adequate, reliable and comprehensive soil information to facilitate the management of soils in Niger State has become imperative for accelerated and sustainable crop production, especially for the cultivation of arable crops. Soils in Niger State are formed from three major parent materials namely: basement complex, sand stone and alluvium. A representative profile pit were studied and the soils were sampled from the genetic horizons, the soils were further characterized and evaluated for arable crop cultivation. Most of the soils are deep and well drained, some are imperfectly drained and have varying amounts of gravels and iron concretions and plinthite. The fine earth fractions of most of the soils are dominated by sand which ranged between 21.2 – 73.2%. generally the soils have low level of organic carbon (10 – 15gkg^{-1}), low to medium levels of total nitrogen (0.6 – 2.0gkg^{-1}), low level of available phosphorus (<3mg kg^{-1} to 7mgkg^{-1}), low cation exchange capacity (6 - 25cmolkg^{-1}) Most of them have high levels of manganese (5.0 – 65.4kg^{-1}) and iron (65.5 – 190kg^{-1}) but low level of copper (0.20 – 3.7gkg^{-1}) and Zinc (0.21 – 3.4gkg^{-1}) The soils were mostly Alfisols and Inceptisols in the higher category of classification (USDA Soil Taxonomy) which correlate with Lixisols and Cambisols in the WRB system. Most of the soils were rated moderately suitable (S2) while others were marginally suitable (S3) for rainfed arable crop cultivation Sustainable crop cultivation will require use of cover crops, minimum tillage, crop rotation, mulching, avoidance of steep and cultivation and fertilizer application (organic and inorganic).
Key words; *Arablecrops;basementcomplex;genetic horizon*

INTRODUCTION

Land is the basic natural resource for agricultural production (crops, forestry, livestock and fisheries). Soil is an important component of land, if we go by definition of land evaluation (Brinkman and Somith, 1973). However, in land evaluation, Soil Survey is an indirect method employed. Soil constitutes the most vital component of the land because most of the complex biophysical and biochemical processes necessary for the sustenance of life and maintenance of the global ecosystem take place in the soil. (Carstea, 2010; Orimoloye, 2010) Soil is the only asset a farmer has, (Ogunkunle, 2016).

Soil characterization, classification and management are geared towards sustainable agricultural production. The need for soil classification and characterization becomes more obvious now more than ever before because of increase in population pressure over the land to meet the food and material requirements of the world teaming population.

Soil characterization pave way to soil survey and land use planning, it as well take in to account the texture, organic matter content, cation exchange capacity acidity and available phosphorus e.t.c all of which have direct influence on the soil suitability. Characterization of soil properties is fundamental to all soil studies. Soil classification is the separation of soils into classes or groups each having similar characteristics and potentially similar behavior (Akinbola*et al.,* 2009)Soil characterization methods draws heavily on methods of soil chemistry, physics, mineralogy, biological and biochemistry.

Soil classification promotes the recognition of similar or identical soils located in different places, thereby facilitating the transfer of knowledge acquired elsewhere to other places. Although different soil studies has been conducted in Niger State, but they are not sufficient to provide adequate, comprehensive and reliable soil information to facilitate efficient and effective management of the soils of Niger State, hence this study was conducted to

Characterize and classify the major types of soils found in Niger State and to evaluate their potentials and their limitations for the production of these selected crops grown in the area.

To suggest some soil management options for sustainable crop production in the area.

MATERIALS AND METHODS

FIELD STUDIES

Representative catena of the three major parent materials on the Niger State soils were selected for this studies, these are Basement Complex, Alluvium, and Granites on sandstones were selected for detailed study. Three modal pits were sunk in each of the Catena, at the mid slope, foot slope and valley bottom. The profile pits were dug to the depth of about 200cm each, except where obstacle (Lithic contact or water tablee.t.c) were encountered, they were described and sampled according to the FAO (2006) guidelines.

LABORATORY STUDIES

Routine laboratory analysis of the soil samples were made in accordance with standard procedures as duly documented by Udo*et al.*, (2009) Characteristics determined were particle size distribution, Bulk density soil reaction, Exchangeable Acidity, organic carbon, Total nitrogen, available Phosphorus, Exchangeable Cations, Base saturation, Cation exchange capacity, extractible ion, Manganese, and Zinc.

Soil Classification was done according to USDA (2014) Soil taxonomy and the WRB (2014) Soil classification Systems. Productive potential of the soils was evaluated according to land capability classification system of the United States Soil Conversation Service (Brady, 1974) while suitability classification for the production of grains, tuber, vegetables was done using the food and Agricultural Organization of the United Nations (FAO, 1976) guide lines.

RESULTS

Soil Morphological Characteristics

The general physiography of the area ranges from gently undulating to relatively flat land. Therefore the soils are deep, well drained and have varying amounts of gravel, iron concentration or plinthite in some horizons. The surface horizons are dark reddish brown (5YR 3/3 moist) reddish brown (7.5YR 5/6 moist) or yellowish red (5YR 4/8. moist) and yellowish brown (10YR 5/6, moist). The subsurface horizons are yellowish red (5YR 4/6. moist), red (2.5YR 4/6. moist). Strongbrown (7.5YR 5/8. moist) or grey (5YR 6/1. moist) and light grey (10YR7 moist).

The surface horizons have weak, medium sub-angular blocky or strong medium angular blocky structure. The subsurface horizons reflect most of the structural classes observed in the surface horizons and in addition, have moderate, coarse angular blocky and strong, coarse angular blocky structure. The textural classes both in the surface and subsurface horizons range from loamy sand to clay.

Physical characteristics

Tables 1, 2 and 3 contain data on some physical characteristics of the soils formed from Basement, Granite and Alluvium deposits respectively. The soils contain varying amounts of coarse fragments ranging from 9.66 % to 92.37 %. The soils formed on Alluvium deposits have less coarse fragments with a mean value of 30.10%, than those formed on Basement or Granites which have mean values of 43.19% and 39.67% respectively. The B and C horizons of soils formed on Alluvium deposits are constantly high in coarse fragments. Sand ranges from 21.2 to 73.2% of the fine earth fraction (< 2 mm) of the soils. The surface horizons are generally higher in sand than the subsurface horizons.

Silt ranges from 3.4 to 59.4% of the fine earth fraction of the soils. The soils are generally high in silt with a mean value of 26.64%. Clay ranges from 2.0 to 45.4% of the fine earth fraction of the soils. The B horizons of most of the soils are higher in clay content than the overlying or underlying horizons. Bulk density ranges from 0.72 to 1.70 gcm^{-3} for the soils, most of the soils have bulk density in the range 1.1 to 1.5 gcm1. Bulk density is relatively lower for soils formed on Basement than for those formed on Granites and Alluvium deposits. The mean bulk density for the soils formed on Basement is 13gcm^{-1} while the values for the soils formed on Granite or Alluvium deposits are 137 gcm° and 1.35 gem^{-1} respectively.

Chemical characteristics

Tables 4, 5 and 6 show the summary of chemical characteristics of the soils. The soils are generally acidic in reaction, the mean pH value is 5.3 (strongly acid). Most of them are in the strongly acid (5.0-5.5) and moderately acid (5.6-6.0) pH ranges. Exchangeable acidity ranges from 0.4-13.9cmol kg'1 for the soils, with a mean value of 4.44cmol kg"1 exchangeable hydrogen accounts for most of the exchange acidity, for a greater portion of the soils as against exchangeable Aluminium. This observation is mostly common in the soils formed from granite.

Organic carbon ranges from very low (0.36gkg^{-1}) to very high (48.26 gkg^{-1}), with most of the soils having moderate to high (10-20gkg^{-1}) contents of organic carbon, the mean value is 12.15 gkg'1 (moderate). The surface horizons of the soils are generally higher in organic carbon than the subsurface horizons. The soils formed on Basement and Granites are generally higher in organic carbon than the soils formed on Alluvium deposits. Total Nitrogen contents of the soils range from 0.03gkg^{-1} (very low) to 3.38 gkg'1 (very high), with most of the soils having low to medium contents (0.6-2.0 gkg'1) of total Nitrogen. The mean value is 1.2" gkg'1 (low). The soils formed on Basement and Granites are relatively higher in Total Nitrogen than those formed on Alluvium deposits.

Available phosphorus of the soils ranges from 0.02mgkg^{-1} (very low) to 16.45mgkg^{-1} (moderate), most of the soils have very low (< 3 mgkg-1) or low (3-7 mgkg"1) available phosphorus. The mean for the soils is 3.56 mgkg1 (low). The soils formed on Granites and Alluvium deposits are generally higher in available phosphorus than those formed on Basement.

Exchangeable cations range from very low to very high for the soils; most of the soils have exchangeable cations in the very low to medium range. The soils formed on Granites have relatively higher levels of exchangeable potassium with a mean of 0.63cmol g^{-1} than those formed on Basement or Alluvium deposits with means 0.41 and 0.40cmol g^{-1} respectively. Similarly, the soils formed on Alluvium deposits are relatively higher in exchangeable sodium than those formed on Basement and Granites. The mean for the soils formed on Alluvium deposits is 0.44cmol kg^{-1}while the soils formed on Basement and Granite has means of 0.30 and 0.40cmol kg^{-1} respectively.

The cation exchange capacity of the soils ranges from 3.52cmol kg^{-1} (very low) to 28.69cmol kg^{-1} (high), with most of the soils having low to moderate (6-25cmol kg^{-1}) cation exchange capacity. The mean for the soils is 13.79cmol kg^{-1}. The Base saturation percentages of the soils range from 35.57% (low) to 96.11% (very high), most of them have moderate to high (40-80%) base saturation percentages. The soils formed on Alluvium deposits have particularly high base saturation percentages with a mean of 71.85% (High) as compared to 67.66 and 66.66% for soils formed on Basalt and Granite respectively.

The soils have extractable manganese in the (0.80-204 gkg"1) range, extractable iron (10.6- 459 gkg"1) range, extractable copper (0.10-5.48gkg^{-1}) range and extractable zinc (0.03-9.3gkg^{-1}) range. The soils formed on Alluvium deposits are higher in copper and zinc than those formed on Granites.

Table 1: Means and ranges of some physical properties of the soils formed on Granite

Pedon	Statistics	B.D	Clay	Silt	Sand	S.Wgt	G.Wgt	% G
				Gkg^{-1}		g		%
Profile MK-BT1-1 (Mid	Minimum	1.20	66	154	500	927	169	16.7
	Maximum	1.30	274	394	580	1624	381	28.96
	Mean	1.26	148	218	537	1181.6	271	23.01
Profile MK-BT1-2 (Foot Slope)	Minimum	1.20	34	174	500	927	268	22.58
	Maximum	1.51	346	274	732	1320	490	37.98
	Mean	1.33	191	230	595	1141	330.4	28.87
Profile MK-BT1-3 (Valley Bottom)	Minimum	1.25	34	234	452	805	296	22.53
	Maximum	1.51	114	434	700	1314	622	71.49
	Mean	1.38	67	314	615	971.8	424.6	45.86
Profile MK-BT2-1 Mid Slope	Minimum	1.10	26	354	352	746.83	108.73	13.8
	Maximum	1.40	240	434	580	1496.86	1382.61	92.37
	Mean	1.23	153	385	462	966.36	521.61	46.83
Profile MK-BT2-2 (Foot Slope)	Minimum	1.20	34	314	431	840.40	270.20	31.77
	Maximum	1.27	205	463	519	1110.30	603.50	64.28
	Mean	1.23	134	392	474	946.5	486.92	51.22
Profile MK-BT2-3 (Valley Bottom)	Minimum	1.20	40	274	360	879.06	309.99	35.26
	Maximum	1.30	266	554	480	1272.18	1036.21	81.71
	Mean	1.28	132.8	430	437.2	1030.28	665.09	63.37

Table 2: Means and ranges of physical properties of the soils formed on Granite.

Pedon	Statistics	B.D	Clay	Silt	Sand	S.Wgt	G.Wgt	% G
		Gcm^{-3}	Gkg^{-1}			g	%	
Profile ED-GT1	Minimum	1.18	274	154	272	501.38	107.34	17.81
Mid Slope	Maximum	1.40	454	334	532	602.61	325.67	81.70
	Mean	1.29	394	230	376	513.91	234.47	47.96
Profile ED-GT1	Minimum	1.22	274	234	272	254.31	94.46	17.46
(profile ED-GT1	Minimum	1.41	454	334	452	540.95	293.00	84.18
	Mean	1.31	378	282	340	402.35	159.18	44.47
Profile ED-GT1-3-3	Minimum	1.15	254	214	212	323.12	204.10	41.94
(Valley bottom)	Maximum	1.59	454	414	472	547.41	326.46	70.09
	Mean	1.32	349	319	332	451.02	247.82	51.41
Profile ED-GT2-1	Minimum	1.3	86	54	340	529.72	81.82	15.45
(Mid Slope)	Maximum	1.5	326	454	640	879.87	348.12	39.56
	Mean	1.4	230	282	488	687.13	179.08	24.59
Profile ED-GT2-2	Minimum	1.3	206	246	352	633.35	103.80	15.37
(Foot Slope)	Maximum	1.5	386	374	534	960.40	420.10	43.74
	Mean	1.4	288	291	421	787.39	260.44	31.51
Profile ED-GT2-3	Minimum	1.4	40	124	366	703.26	159.35	22.66
(Valley Bottom)	Maximum	1.6	280	594	506	1247.03	613.56	58.60
	Mean	1.5	100	403	433	989.57	391.20	38.13

Table 3: Means and ranges of some physical properties of the soils formed on Alluvium

Pedon	**Statistics**	**B D gem^{-3}**	**Clay**	**Silt**	**Sand**	**S.Wgt**	**G. Wgt**	**%G**
				gkg^{-1}		g		**%**
Profile -MK UD1–1 (Mid Slope)	Minimum	0.93	202	180	358	446.33	61.33	10.60
	Maximum	1.55	402	380	618	660.56	226.21	5065
	Mean	1.15	310	256	434	593.36	130.13	23.54
Profile MK – UD1-2 (Foot Slope)	Minimum	1.06	108	200	358	479.67	148.47	24.55
	Maximum	1.55	348	434	458	604.80	291.51	56.92
	Mean	1.37	262	244	433	543.20	221.18	41.06
Profile MK – UD1-3 (Valley Bottom)	Minimum	0.72	248	294	258	561.70	75.48	12.01
	Maximum	1.63	408	334	334	660.30	231.52	41.22
	Mean	1.09	343	319	338	616.48	158.08	26.25
Profile MK– UD2-1 (Mtd Slope)	Minimum	1.35	66	34	440	711.99	78.50	9.66
	Maximum	1.70	280	374	740	1083.4	452.62	54.39
	Mean	1.53	185	201	612	830.56	194.86	23.40
Profile MK – UD2-2 (Foot Slope)	Minimum	1.5	126	254	340	657.79	134.79	17.86
	Maximum	1.6	286	534	460	754.57	340.19	51.72
	Mean	1.55	226	384	390	703.9	246.88	35.57
Profile MK – UD2-3 (Valley Bottom)	Minimum	1.4	20	214	340	705.34	101.44	44.38
	Maximum	1.5	306	434	546	1062.71	449.64	59.08
	Mean	1.43	220	329	452	812.88	256.47	30.76

Table 4: Means and ranges of some chemical properties of the soils formed on Basement

Pedon	Statistics	pH H_20	OC	TN	Av.P	Ex.A	H+	$A1^{3+}$	Ca	Mg	K	Na	CEC	BS	Mn	Fc	Cu	Zn
			gkg^{-1}		$mgkg^{-1}$	cmol kg^{1}								%	mg kg-1			
Profile MK-	Minimum	5.0	6.72	0.71	0.02	0.8	0.8	0.0	2.03	0.34	0.11	0.26	4.62	54.63	9.2	50.1	1.05	0.31
BT1–1 (Mid Slope)	Maximum	5.4	21.42	2.22	2.22	2.4	0.6	0.6	2.24	1.50	0.25	0.40	5.31	82.68	64.8	75.6	1.54	2.53
	Mean	5.2	12.94	1.34	1.34	1.6	0.28	0.28	2.13	0.75	0.16	0.33	4.96	67.96	26.42	61.72	1.28	0.99
Profile MK –	Minimum	5.0	7.96	0.83	0.04	1.2	1.2	0.0	2.05	0.15	0.13	0.19	5.04	35.57	15.3	47.5	0.87	0.27
BT1-2 (Foot Slope)	Maximum	2.2	22.26	2.30	2.95	4.8	3.4	1.4	2.25	1.28	0.23	0.38	7.45	76.19	74.5	85.4	3.34	3.12
	Mean	5.1	13.69	1.42	1.40	2.82	2.18	0.64	2.17	0.90	0.16	0.29	6.34	57.15	37.8	58.8	1.67	1.14
Profile MK – BT1-3 (Valley	Minimum	5.4	1.98	0.22	0.02	0.4	0.4	0.0	2.20	0.20	0.10	0.29	3.52	58.63	18.6	24.5	1.05	0.61
Bottom)	Maximum	6.1	21.42	2.22	10.08	2.3	1.5	0.8	2.36	0.97	0.26	0.38	5.56	89.56	70.6	137.0	2.87	1.49
	Mean	5.7	8.34	0.87	3.15	1.0	0.8	0.2	2.28	0.54	0.18	0.32	4.30	78.95	48.26	85.9	1.64	1.00
Profile MK – BT2-1 (Mid	Minimum	4.5	0.76	0.08	0.34	4.3	0.4	3.1	8.11	0.80	0.56	0.18	14.06	60.77	12.00	24.10	0.16	1.90
Slope)	Maximum	6.0	25.39	2.63	9.71	8.0	1.8	6.2	8.51	5.52	1.18	0.40	20.39	69.43	78.10	276.0	0.84	9.30
	Mean	5.4	12.00	1.24	4.18	5.72	1.1	4.6	8.32	1.47	0.77	0.27	16.56	65.90	4384	175.22	0.46	4.58
Profile MK – BT2-2 (Foot	Minimum	4.7	5.0	0.52	0.65	4.50	0.7	3.0	8.14	1.0	0.49	0.20	15.21	62.78	50.50	138.5	0.32	1.80
Slope)	Maximum	5.7	20.60	2.0	6.40	6.50	1.8	4.9	8.8	2.5	0.80	0.41	18.60	71.15	102.0	212.0	1.32	7.80
	Mean	5.24	11.32	1.15	2.56	2.56	1.22	4.2	8.49	1.7	0.62	0.30	16.54	67.34	79.11	186.7	0.74	3.93
Profile MK – 2-3 (VBT2-	Minimum	4.7	3.23	0.34	0.13	4.7	0.8	3.5	7.86	1.26	0.31	0.18	15.76	64.42	73.70	109.0	0.31	0.52
3alley Bottom)	Maximum	5.5	15.72	1.63	3.05	5.7	1.6	4.6	9.58	2.70	0.88	0.33	17.36	72.92	146.0	261.0	1.33	6.64
	Mean	5.0	10.40	1.08	1.29	5.2	1.1	4.1	8.72	1.96	0.54	0.26	16.68	68.70	110.6	174.6	0.85	2.04

Table 5: Means and ranges of some chemical properties of the soils formed on Granite

Pedon	Statistics	pH H_20	OC	TN	Av.P	Ex.A	H+	$A1^{3+}$	Ca	Mg	K	Na	CEC	BS	Mn	Fc	Cu	Zn
			gkg^{-1}		$mgkg^{-1}$				cmol	kg^{1}				%	mg kg-1			
Profile MK-	Minimum	5.23	9.88	0.86	2.13	2.50	0.70	0.00	5.99	0.95	0.18	0.52	11.76	52.71	4.3	10.60	2.02	1.16
GT1–1 (Mid Slope)	Maximum	5.54	31.90	2.96	9.01	6.90	2.50	5.50	8.66	2.19	0.35	0.61	17.59	78.74	66.8	61.7	2.58	1.64
	Mean	5.44	21.17	1.97	4.30	5.14	1.66	3.48	6.93	1.40	0.24	0.56	14.27	64.64	23.04	36.14	2.23	1.34
Profile MK –	Minimum	5.14	4.94	0.38	1.61	1.25	0.70	0.00	6.06	1.27	0.53	0.43	9.78	51.05	4.0	45.6	2.35	1.28
GT-2 (Foot Slope)	Maximum	5.57	48.26	3.38	14.40	9.10	3.10	6.00	14.57	6.41	1.93	0.57	28.69	87.22	204.0	331.0	3.25	1.80
	Mean	5.4	20.37	1.65	5.13	4.65	1.72	2.93	8.21	2.81	1.04	0.49	17.19	74.17	47.0	128.46	2.57	1.60
Profile MK – GT 1-3	Minimum	5.23	9.50	0.81	0.68	0.75	0.75	0.00	6.49	1.10	0.31	0.52	11.0	73.60	17.4	43.6	2.25	1.29
(Valley Bottom)	Maximum	5.51	17.86	1.61	10.66	3.35	3.35	0.00	10.18	2.89	0.59	0.61	15.35	93.87	59.9	148.0	4.16	1.41
	Mean	5.33	13.74	1.23	6.09	1.78	1.78	0.00	8.07	1.92	0.47	0.58	12.82	85.86	39.33	82.23	3.19	1.36

Table 6: Means and ranges of some chemical properties of the soils formed on Granite

Pedon	Statistics	pH H_20	OC	TN	Av.P	Ex.A	H+	A1^{3+}	Ca	Mg	K	Na	CEC	BS	Mn	Fc	Cu	Zn
			gkg^{-1}		mgkg^{-1}				cmol	kg^{-1}				%	mg kg-1			
Profile MK- GT1–1 (Mid Slope)	Minimum	4.8	6.05	0.63	0.09	3.8	1.4	2.0	6.79	0.10	0.25	0.14	12.7	41.18	0.80	102	0.52	0.03
	Maximum	5.7	18.28	1.89	2.55	11.9	5.8	6.1	7.44	1.05	0.65	0.26	20.23	70.08	5.30	277	1.77	2.24
	Mean	5.12	12.54	1.30	0.67	6.7	3.0	3.7	7.13	0.35	0.39	0.19	14.72	56.34	3.70	175.6	0.99	0.91
Profile MK – GT-2 (Foot Slope)	Minimum	4.6	0.77	0.08	0.08	4.6	1.0	3.6	7.40	0.22	0.60	0.17	14.0	56.31	2.1	25	0.31	0.57
	Maximum	5.8	22.95	2.37	3.81	8.2	2.3	6.0	9.43	1.02	1.45	0.34	18.77	67.30	242	196	0.67	8.00
	Mean	4.9	9.87	1.02	1.04	5.8	1.6	4.2	8.59	0.56	0.86	0.25	16.21	63.48	101.76	123.4	0.45	3.16
Profile MK – GT 1-3 (Valley Bottom)	Minimum	4.8	0.36	0.03	0.44	4.5	0.1	4.4	7.09	0.14	0.32	0.17	12.98	47.02	4.30	88	0.21	0.31
	Maximum	5.0	16.52	1.71	2.79	8.9	4.4	5.3	7.39	0.47	1.68	0.43	17.04	65.33	36.80	242	0.53	4.99
	Mean	4.9	9.59	0.99	1.29	6.98	2.3	4.7	7.18	0.26	0.75	0.27	15.44	55.45	18.14	139.6	0.36	2.20

Table 7: Means and ranges of some chemical properties of the soils formed on Alluvium

Pedon	Statistics	pH H_20	OC	TN	Av.P	Ex.A	H+	A1^{3+}	Ca	Mg	K	Na	CEC	BS	Mn	Fc	Cu	Zn
			gkg^{-1}		mgkg^{-1}				cmol	kg^{-1}				%	mg kg-1			
Profile MK- GT1–1 (Mtd Slope)	Minimum	5.66	13.83	1.46	2.90	0.7	0.7	0.0	6.94	1.61	0.09	0.22	11.00	80.91	8.3	63.1	2.45	2.31
	Maximum	6.01	17.91	1.87	13.35	2.2	2.2	0.0	12.77	2.57	0.20	0.70	17.75	94.33	42.6	308.0	4.54	5.69
	Mean	5.79	15.94	1.64	6.73	1.74	1.74	0.0	10.01	2.03	0.15	0.41	14.27	87.50	24.06	148.64	3.38	3.72
Profile MK – GT-2 (Foot Slope)	Minimum	5.98	4.30	0.51	4.03	0.6	0.6	0.0	6.51	1.69	0.08	0.35	11.72	85.49	6.8	51.4	2.93	3.87
	Maximum	6.10	12.62	1.31	16.31	1.7	1.7	0.0	13.95	2.73	0.18	1.21	18.97	96.11	19.0	196.0	5.48	4.78
	Mean	6.05	9.96	1.09	7.35	1.05	1.05	0.0	11.24	2.32	0.14	0.76	15.50	92.67	15.35	90.2	3.74	4.18
Profile MK – GT 1-3 (Valley Bottom)	Minimum	5.88	4.48	0.52	3.96	1.8	1.8	0.0	8.03	1.32	0.04	0.52	12.70	82.68	7.6	28.6	3.56	2.51
	Maximum	7.04	8.55	0.91	16.45	2.4	2.4	0.0	11.80	2.95	0.17	1.04	18.36	86.93	26.8	104.5	4.33	4.46
	Mean	6.23	6.14	0.70	12.69	2.13	2.13	0.1	9.43	2.01	0.11	0.76	14.44	85.09	14.6	55.48	3.91	3.49
Profile MK- UD2–1 (Mid Slope)	Minimum	4.6	3.22	0.21	0.09	4.8	1.1	2.3	7.01	0.31	0.23	0.19	13.99	36.65	3.5	81	0.34	0.03
	Maximum	4.9	28.37	2.42	4.71	13.9	8.3	5.6	7.71	0.50	1.39	0.41	21.94	66.53	22.4	459	0.89	3.27
	Mean	4.76	13.03	1.15	1.80	7.7	3.1	4.5	7.39	0.35	0.78	0.25	16.43	55.07	8.98	180.4	0.54	1.28
Profile MK – UD2-2 (Foot Slope)	Minimum	4.6	0.68	0.10	0.44	3.3	1.6	1.7	7.09	0.15	0.29	0.10	11.15	49.56	2.1	93	0.63	0.52
	Maximum	5.1	16.52	1.71	1.52	8.5	3.8	5.3	7.83	0.43	1.23	0.43	17.27	70.40	9.2	299	0.92	4.20

	Mean	4.9	9.23	0.96	0.83	6.43	2.8	3.68	7.49	0.32	0.74	0.28	15.25	59.03	5.93	160.3	0.75	2.21
Profile MK – UD 2-3 (Valley Bottom)	Minimum	4.8	0.81	0.08	1.40	4.3	1.5	2.8	6.84	0.17	0.22	0.11	12.64	39.08	16	59	0.10	0.51
	Maximum	5.0	14.51	1.80	4.57	11.6	8.2	5.6	7.66	0.62	0.76	0.26	19.04	65.98	68	134	1.05	2.06
	Mean	4.93	8.45	1.00	2.59	8.1	4.03	4.08	7.29	0.33	0.42	0.18	16.30	51.73	34	83.5	0.45	1.03

Table 8: Classification of the soils in accordance with both the USDA soil Taxonomy (2014) and WRB (2014) systems

Soils	Slope Position	USDA Soil Taxonomy (2014)	WRB (2014)
Soils formed on Basement Complex			
MK – BT 1-1	Mid slope	ArenicCalciustept	RhodicCambisol
MK – BT 1-2	Foot Slope	AquicArenicNatrustalf	Ferric Lixisol
MK– BT 1-3	Valley Bottom	ArenicCalciustept	RhodicCambisol
MK– BT 2-1	Mid Slope	PetrocalcicNatrustalf	Ferric Lixisol
MK– BT 2-2	Foot Slope	Petrocalcicnatrustalf	Ferric Lixisol
MK– BT 2-3	Valley Bottom	Aquiccalciustept	CalcaricCambisol
Soils formed on Alluvium			
MK –GT 1-1	Mid slope	PlinthicKandiustalf	Ferric Lixisol
MK– GT 1-2	Foot Slope	PlinthicKandiustalf	Ferric Lixisol
MK– GT 1-3	Valley Bottom	PlinthicKandiustalf	Ferric Lixisol
MK– GT 2-1	Mid Slope	PetrocalcicNatrustalf	Ferric Lixisol
MK– GT 2-2	Foot Slope	AquicNatrustalf	Ferric Lixisol
MK– GT 2-3	Valley Bottom	AquicCalciustept	CalcaricCambisol
Soils formed on Granite/Nupe sandstone			
MK–UD 1-1	Mid slope	PetrocalcicNatrustalf	Ferric Lixisol
MK- UD 1-2	Foot Slope	AquicNatrustalf	Ferric Lixisol
MK – UD 1-3	Valley Bottom	PlinthaquicKandiustalf	Ferric Lixisol
MK– UD 2-1	Mid Slope	AquicKandiustalf	Ferric Lixisol
MK– UD 2-2	Foot Slope	PetrocalcicNatrustalf	Ferric Lixisol
MK– UD 2-3	Valley Bottom	AquicNatrustalf	Ferric Lixisol

Table 9: Land capability classes of the soils

Soils	Slope Position	Land Capability classes
Soils formed on Basement		
MK – BT 1-1	Mid slope	IIIe -^{2}
MK– BT 1-2	Foot Slope	IIe – ^{1}
MK– BT 1-3	Valley Bottom	IIw – ^{1}
MK– BT 2-1	Mid Slope	IIe – ^{1}
MK– BT 2-2	Foot Slope	IIe – ^{1}
MK– BT 2.3	Valley Bottom	IIw – ^{1}
Soils formed on Alluvium	Mid slope	IIIe -^{2}
MK– GT 1-1	Foot Slope	IIe – ^{1}
MK– GT 1-2	Valley Bottom	IIw – ^{1}
MK– GT 1-3	Mid Slope	IIe – ^{2}
MK– GT 2-1	Foot Slope	IIe – ^{1}
MK– GT 2-2	Valley Bottom	IIw – ^{1}
MK– GT 2.3		
Soils formed on Granite/Nupe sandstone		
MK– UD 1-1	Mid slope	IIIe -^{2}
MK– UD 1-2	Foot Slope	IIe – ^{1}
MK– UD 1-3	Valley Bottom	IIw – ^{1}
MK– UD 2-1	Mid Slope	IIe – ^{2}
MK– UD 2-2	Foot Slope	IIe – ^{1}
MK– UD 2.3	Valley Bottom	IIw – ^{1}

Table 11: Land suitability classes of the soils

Soils	Slope Position	Rainfed arable farming			
		Grains	**Tubets**	**Vegetables**	**Tree Crops**
		Maize, Millet, Sorghum	Yam, Potato, cassava	Amaranthus, Celosia	Mango, Citrus,
Soils formed on Basement					
MK-BT 1 – 1	Mid slope	S2e-2	S2e-2	S2e-1	S2e-2
MK-BT 1 – 2	Foot Slope	S2e-1	S2e-1	S2e-1	S2e-1
MK-BT 1 – 3	Valley Bottom	S2s-1	S2s-1	S2s-1	S2s-1
MK-BT 2 – 1	Mid Slope	S2e-2	S2e-2	S2e-1	S2e-2
MK-BT 2 – 2	Foot Slope	S2e-1	S2e-1	S2e-1	S2e-1
MK-BT 2 – 3	Valley Bottom	S2w-1	S2w-2	S2w-1	S2w-2
Soils formed					
on Alluvium			S2e-2		S2e-2
MK-GT 1 – 1	Mid slope	S2e-2	S2e-1	S2e-1	S2e-1
MK-GT 1 – 2	Foot Slope	S2e-1	S2s-1	S2e-1	S2s-1
MK-GT 1 – 3	Valley Bottom	S2s-1	S2e-2	S2s-1	S2e-2
MK-GT 2 – 1	Mid Slope	S2e-2	S2e-1	S2e-1	S2e-1
MK-GT 2 – 2	Foot Slope	S2e-1	S2w-2	S2e-1	S2w-2
MK-GT 2 – 3	Valley Bottom	S2w-1		S2w-1	
Soils formed on					
Granie/Nupe			S2e-2		S2e-2
sandstone	Mid slope	S2e-2	S2e-1	S2e-1	S2e-1
MK-UD 1 – 1	Foot Slope	S2e-1	S2s-1	S2e-1	S2s-1
MK- UD 1 –	Valley Bottom	S2s-1	S2e-1	S2s-1	S2e-1
MK- UD 1 –	Mid Slope	S2e-1	S2e-1	S2e-1	S2e-1
MK- UD 2 – 1	Foot Slope	S2e-1	S2w-2	S2e-1	S2w-2
MK- UD 2 – 2	Valley Bottom	S2w-1		S2w-1	
MK- UD 2 – 3					

Table 7 contains detailed classification of the soils investigated, in both the USDA(2014) soil taxonomic classification and the WRB (2014) soil classification systems. The soils were classified as AquicKandiustalf (Ferric Lixisol), PlinthaquicKandiustalf (Ferric Lixisol), ArenicCalciustept (RhodicCambisol), AquicCalciustept (CalcaricCambisol) and PetrocalcicNatrustalf (Ferric Lixisol) among others.

The land capability classes of the soils are contained in Table 8. The soils are in Land capability classes II to IV. Table 9 contains the suitability classes of the soils for rainfed arable farming, most of the soils are moderately suitable land (S2) while the others are marginally suitable land (S3).

DISCUSSION

The surface soils are high in sand; this may be attributed to the Aeolian deposition of a fine yellowish loamy material over much of the Plateau (Macloed*et al*., 1971). Again, the washing away of fine soil materials by moving water leaving behind the course materials may be another reason. Esu (1982) has attributed the relatively higher fine sand in the upper horizons of some of the soils he studied in Kaduna area of Nigeria, to the Aeolian sources of the soil parent material of the upper layers of the soils.

The high silt contents of the soils differentiate them from the soils of the humid tropical low lands of South-west Nigeria (Ojanuga, 1981) but make them similar to those of Kaduna area studied by Esu (1982). The higher silt contents of the soils formed on Basement and Granite over those formed on Alluvium deposits, may be due to the fact that the soils formed on Alluvium deposits were products of erosional processes and deposition whereas the other two categories were formed in situ.

The higher contents of clay in the B horizons of most of the soils as compared to the other horizons may be attributed to deposition of clay, from the overlying horizons.

The Bulk density of most of the soils range from 1.1 to 1.5 gem^{-3}, Dc Geus (1973) and Vapraskas (1977), have noted that Bulk density above 1.46 to 1.63 gem^{-3} for loams and Clays result in hindrance to root penetration and insufficient aeration due to compaction. Most of the soils investigated in this study will not hinder root penetration and good aeration because of their low or moderate Bulk densities. The acid nature of most of the soils could be attributed to heavy relief rainfall, parent material effect and the use of acid forming fertilizers. (Bornemisza, 1988) has observed that under a soil pH range of 4.0-5.0, Phosphorus becomes unavailable to plants, bacterial nitrification decreases and A1 toxicity could possibly increase. (Wiechmann, 1987), has noted that such acid related problems constitute limitation to crop production. Liming will improve the availability of phosphorus to crops, for most ofthe soils.

Exchangeable Hydrogen accounts for most ofthe exchangeable acidity of most of the soils; this may be attributed to the leaching of basic tons due to the heavy rainfall received on the Jos Plateau, leaving behind the Hydrogen ions on the exchange sites.

The higher contents of the organic carbon in the surface horizons ofthe soils over those of the subsurface horizons may be attributed to the influence of plants and crops residues received by the surface horizons. Farm yard manures often applied by farmers, could be another contributory factor. The higher organic carbon contents of the soils formed on Basement and Granites over those formed on Alluvium deposits may be attributed to the parent material effects.

Olowolafe (2003), reported organic matter of more than 2% and sometimes up to 3% for most of the soils derived from Basement and volcanic ash, on the Jos Plateau especially in the Surface layers.

Ladon (1991) has noted that organic carbon contents below 2% in tropical soils are very low due to high temperature in most period oftheyear loading to high rates of decomposition, mineralization and disappearance of organic materials, thereby preventing appreciable accumulation of organic carbon in the soils. Considering the important roles of organic matter in the sustainability of tropical agriculture, (Mulongoy and Merck x, 1993).the very low or low contents of organic carbon in some of the soils investigated, constitute a serious constraint to sustainable crop production. Most of the soils have low to medium levels ofTotal Nitrogen (0.6-2.0 gkg"1) and will require judicious application of Nitrogen fertilizers for sustainable crop production. The inadequate levels of Total Nitrogen in most of the soils may be due to leaching and erosion as a result of heavy rainfall. Furthermore, most of the soils have been intensively cultivated for long without adequate return of organic matter.

The higher levels of Total Nitrogen in the surface horizons of the soils may be attributed to the influence of organic matter. The relatively high levels ofTotal Nitrogen in soils formed on Basement and Granites over those formed on Alluvium deposits, may be attributed partly to their higher contents of organic matter over those formed on Alluvium deposits. Again, the unconsolidated deposits were a product of mass movement and deposition of materials by water; they could have lost some of the Nitrogen they carry, to water.

The very low available phosphorus of most of the soils may be partly due to the strongly acid or moderately acid conditions of most of the soils, resulting in the fixation of phosphorus. Again, some of the soils are very low or low in organic matter, since organic matter is a reservoir of many nutrient elements including phosphorus, the very low or low levels of available phosphorus of some of the soils, is partly explained by their very low or low levels of organic matter. The very low or low levels of available phosphorus of most of the soils suggest that sustainable crop production may not be possible without the application of phosphorus fertilizers. The acid conditions of most of the soils suggests that liming could be beneficial to crop production using the soils as the phosphorus fixed will become available to crops.

The higher levels of available phosphorus in soils formed on Granites and Basement deposits over those formed on Alluvium, may probably be due to the presence of allophone in the soils formed on Basement, which make them to react with phosphorus and reducing the availability of the nutrient element. Egawa (1977), Uehara and Gillman (1981), have observed that volcanic soils are characterized by their capability to react rapidly with large amounts of phosphorus due to their allophone contents.

With most of the soils having exchangeable cations in very low to moderate range, sustainable crop production with the soils may not be possible without the application of the nutrients as fertilizers, to make up for the deficits.

The higher levels of exchangeable potassium of soils formed on Granites over those formed on Basement and Alluvium deposits, may be due to the parent material effects, the Granites may be rich in minerals containing potassium such as feldspars. Similarly, the higher levels of sodium in the soils formed on unconsolidated deposits over those formed on Granites and Basement may be due to the parent material effects; the Alluvium deposits may be rich in dissolved sodium salts. The very low cation exchange capacity of the soils formed on Basement as against the moderate cation exchange capacity of most of the soils formed on Granites and Alluvium deposits may be attributed to the lower clay and organic carbon contents of the Basement soils. Furthermore, leaching of cations may have been more in the Basement soils which are more porous.

The moderate to high Base saturation percentages of most of the soils may be attributed to the parent material effects and the influence on organic matter. The parent rocks (Metamorphic, Granites, etc), are rich in minerals such as feldspar and micas amongst others which in turn are rich in basic cations. The high (60-80%) to very high (80-100%) Base saturation percentages of most of the soils formed on Alluvium deposits may be attributed to dissolved salts, clay minerals in the rock components and the influence of organic matter.

The constantly high Base saturation percentages of the surface horizons and the B horizons of all the soils may be attributed to the influence of organic matter and clay respectively.

Most of the soils have sufficient levels of manganese and iron for sustainable crop production; the levels of zinc and copper are however insufficient and would need to be added as supplements. The relatively high levels of Zinc and Copper in the soils formed on unconsolidated deposits over those formed on Basement and Granites, may be due to the parent material effects.

Most of the soils at the crest positions in the toposequences of soils formed on Basement and Granites are Inceptisols, they are young soils and soil development processes are just at the early stage. In the mid slope, foot slope and valley bottom positions, the soils are Alfisols or Ultisols, they are well developed and soil development processes are at the advanced stage, the soils are also deeper. Olowolafe (2003) made a similar observation for some of the soils of Niger State that he studied. Orimoloye (2010) made similar findings for some of the rubber soils of Cross River State that he investigated.

The hazard of erosion which in turn depends largely on the slope of the land, determines the capability classes of the soils. Soils in the crest Position belongs to the marginal arable land capability class; soils in the upper and mid slope positions, belong to the moderate arable land capability class while soils in the foot slope and valley bottom positions are good arable land. The land suitability classes into which the soil belong for rainfed arable farming, follow a similar trend to those of the capability classes; with the slope of the land and hazard of the erosion being a major determinant of the suitability class into which a soil belongs. Soils in the crest positions are marginally suitable and belong to land suitability class (S3). The nature of the arable crop too, plays a role in the suitability class into which a soil is placed.

The soils share similar problems and require similar management practices for sustainable crop production. The following soil management and conservation practices should be adopted for the soils:

(i) Mulching/Use of cover crops
(ii) Minimum tillage
(iii) Avoidance of steep land for cultivation whenever possible
(iv) (iv) Contour cultivation
(v) (v) Use of light tillage implements
(vi) (vi) Liming
(vii) (vii) Avoidance of acid forming fertilizers
(viii) Complementary use of inorganic and organic fertilizers
(ix) Split application of fertilizers
(x) Fertilizer application should be based on soil tests and crop requirements
(xi) Crop rotation

SUMMARY AND CONCLUSION

Even though a number of soil studies have been conducted in Niger State, there is need to provide adequate, comprehensive and reliable soil information to facilitate efficient management of soils of the Niger State for accelerated and sustainable crop production especially the cultivation of special crops such asrice, maize, sorghum, and yam.

The objectives of this study are: providing more, reliable and comprehensive information on the soils of the Niger State to enhance their better understanding and utilization; classifying them using internally recognized systems to enhance their identification; evaluating their potentials and limitations for the major crops grown on the soils of Niger State and formulating soil management and conservation practices for sustainable crop production in the agro-climate region.

The fine earth fraction of most of the soils is dominated by sand; the soils are generally high in sill. The B horizons of most of the soils and higher in clay than the other horizons. The soils are generally acid in reaction; they have adequate levels of organic carbon. Most of the soils have low to medium levels of Total Nitrogen, very low or low levels of available phosphorus, very low to moderate levels of exchangeable cations and low to moderate cation exchange capacity. The soils have sufficient levels of manganese and iron but insufficient levels of zinc and copper.

In both the USDA (2014) and WRB (2014) soil classification systems, the soils have been classified as AquicKandiustalf (Ferric Lixisol), PlinthaquicKandiustalf (Ferric Lixisol), ArenicCalciustept (RhodicCambisol), AquicCalciustept (CalcaricCambisol) and PetrocalcicNatrustalf (Ferric Lixisol) among others. The soils belong to land capability classes II to IV and suitability classes (S2) and (S3) for rainfed arable farming involving some popular crops grown in Niger State. Soil management and conservation practices recommended for sustainable crop production using the soils include: mulching, cover cropping, minimum tillage, contour cultivation, crop rotation and fertilizer application based on soil tests and crop requirements among others.

In conclusion, the soils investigated are generally acid, inadequate in most nutrient elements and require well-articulated, efficient and effective soil management and conservation practices for sustainable crop production.

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