Agro-Science Journal of Tropical Agriculture, Food, Environment and Extension
Volume 21 Number 3 (July 2022) pp. 94 - 100
ISSN 1119-7455

FERTILITY CAPABILITY CLASSIFICATION OF SELECTED SOILS ON THE BASEMENT COMPLEX OF NORTH-EASTERN NIGERIA

[*1]Kefas P.K., [2]Maniyunda L.M., [2]Shobayo A.B., [3]Garjila Y.A., [4]Philip H.J. and [1]Christopher A.

[1]Department of Soil Science & Land Resource Management, Faculty of Agriculture, Taraba State University, PMB 1167 – Jalingo, Taraba State, Nigeria
[2]Department of Soil Science, Faculty of Agriculture/Institute for Agricultural Research, Ahmadu Bello University, PMB 1044 – Zaria, Kaduna State, Nigeria
[3]Department of Agronomy, Faculty of Agriculture, Federal University of Kashere, Gombe State, Nigeria
[4]Department of Soil Science, Faculty of Agriculture, Federal University PMB 1005 – Gashua, Yobe State, Nigeria

*Corresponding author's email: pkefas@yahoo.com

ABSTRACT
A clear understanding of soil characteristics and their appropriate classification are essential for efficient land use and increased productivity. The present study was carried out to obtain the fertility capability classification (FCC) of the soils overlying the basement complex in a toposequence in north eastern Nigeria and to serve as baseline data for soil management. Soils on four topographic positions identified on porphyritic granite (PG), pegmatite (PT) and granite-gneiss (GG) of the basement complex in Taraba State of Nigeria were assessed. Twelve pedons were studied in all, four along the toposequence on PG, PT, and GG. At the type and substrata type, sandy and loamy group dominated. Ustic soil moisture regime, exchange acidity (fixing available phosphorus) and low organic carbon limited the entire soils across the basement complexes restricting rainfed crop production to one season per annum except with irrigation practice. Poor drainage was a limitation across the soils on pegmatite. The FCC rated PG and GG soils as SLdeam (sand over loam and limited by moisture, effective cation exchange capacity, aluminium toxicity and organic carbon) and Ldam (loam type and substrata characteristics limited by moisture, aluminium toxicity and organic carbon), and PT and PT soils as Sdamg (sandy type and substrata type restricted by moisture, aluminium toxicity, organic carbon, drainage). Ridge construction, organic and mineral fertilizer applications are essential management practices required for sustainable use of these soils.

Key words: fertility capability classification, basement complex, northern Guinea Savannah

INTRODUCTION
The characteristics of any soil and its ability to supply the required plant nutrients are largely determined by the parent material and influenced by climate, topography, land use and management (Ibia and Udo, 2009; Udoh *et al.,* 2013). Soils derived from the basement complex are granitic and coarse in nature (Kefas, 2021). The current shortage of food and increasing food requirements for the rapidly expanding population necessitate that the basement complex, hitherto under-utilized, be brought under intensive agricultural land use. Available information about the basement complex soils is insufficient for efficient scientific planning for the future use of the soils for agriculture. A clear understanding of the characteristics and classification of the various soil types is essential for efficient management and increased productivity of the basement complex soils.

The fertility capability classification (FCC) system is a suitable framework for agronomic soil taxonomy. It is acceptable to both pedologists and agronomists (Lin, 1989; Udoh *et al.,* 2013). The FCC units are groups of soils with similar kinds of problems and requirements for agronomic management of their chemical and physical properties in a given location. Crop production in the northern Guinea Savannah of Nigeria focuses on cereals like millet, sorghum, maize and wheat, as well as legumes like cowpea, groundnut and soybean (Ajeigbe and Singh, 2010; Foli, 2012). Though livestock is important in the farming system of the area (Smith *et al*., 1997), it is often integrated with crops (Foli, 2012) as both have reciprocal benefits. Farmers in the region combine organic and inorganic inputs as well as encourage cereal-legume mixtures to consciously manage and improve soil fertility (Harris, 1998; Hoffmann and Gerling, 2001).

The present study was carried out to classify the fertility capability of soils developed over landscapes as a baseline for soils on basement complexes in North-East of Nigeria and provide basic information for soil management. The soils were also classified according to the requirements of the United States Department of Agriculture (USDA) system of soil classification (Soil Survey Staff, 2014) and correlated with the World Reference Base (WRB) for soil resources system (World Reference Base, 2014).

Please cite as: Kefas P.K., Maniyunda L.M., Shobayo A.B., Garjila Y.A., Philip H.J. and Christopher A. (2022). Fertility capability classification of selected soils on the basement complex of north-eastern Nigeria. *Agro-Science*, **21 (3),** 94-100. DOI: https://dx.doi.org/10.4314/as.v21i3.11

MATERIALS AND METHODS

Description of the Study Area

The study was conducted in Taraba State (latitudes 6° 30', 9° 30' N; longitudes 9° 00', 12° 00' E), North-East, Nigeria. The selected study sites were in Kona (latitude 8° 57' 0'' N; longitude 11° 21' 0''E; 393 m asl), Garin-mallum (latitude 8° 51' 0'' N; longitude 11° 18' 0'' E; 268 m asl) and Bakin-Dutse (latitude 8° 50' 14.6'' N; longitude 11° 17' 43'' E; 247 m asl). Undifferentiated basement complex rocks dominate the geology of the area, with Precambrian granitic and migmatite gneisses and their outcrops occurring at intervals. The study area is characterized by tropical climate with distinct wet (7 months) and dry (5 months) seasons. Mean annual rainfall ranges from 800 mm in the northern zone to over 2000 mm in the southern zone of the State. Rainfall is lowest in January with a peak in August (217 mm). Mean annual temperature varies from 28.4°C in the coolest month of December to 37°C in the hottest month of March (NIMET, 2009). Taraba State is characterized by guinea savannah, sub-sudan vegetation and a somehat semi-temperate climate with luxuriant pasture and short trees in the Mambilla plateau area.

Field Study

Reconnaissance visits were carried out to the three sites underlying the three lithologies that were identified as porphyritic-granite (PG) at Kona, granite-gneiss (GG) at Garin-mallum and pegmatite (PT) at Bakin-Dutse. The identification of the lithologies was aided by the geological map of Taraba State obtained from the Nigerian Geological Survey Agency. These geologic materials occupy a vast expanse with broad agricultural value. Soil profile pits were sunk along the toposequence of each geologic formation and the modal representative pits were used for each topographic position from crest (CS), upper slope (US), middle slope (MS) to lower slope (LS). Twelve (12) profile pits were used for the study. Each profile pit was described according to the guideline for soil profile description (Schoeneberger *et al.*, 2012) and samples collected from identified soil horizons into polythene bags that were carefully labeled and taken to the laboratory for physical and chemical analysis.

Laboratory Analysis

Particle size distribution was determined using the hydrometer method as modified by (Udo *et al.,* 2009). At a ratio of 1:1 for water:soil, soil pH was determined with glass electrode pH meter (Maclean, 1982). Organic carbon was determined by the dichromate wet oxidation method of Walkley and Black (1934) as modified by Udo *et al.* (2009). Total nitrogen was determined by the macro-Kjedahl digestion distillation method of Bremner and Mulvaney (1982). Available phosphorus was extracted with Bray No 1 solution (Bray and Kurtz , 1945) and determined colourimetrically as modified by Udo *et al.* (2009). Exchangeable acidity was determined by the titration methods from the wet extract using 1 N HCl. Effective cation exchange capacity was obtained by summation of exchangeable bases and total exchangeable acidity. Results of morphological, physical and chemical properties of the top 50 cm depth horizons were used for the study. The soils were classified according to the criteria of United States Department of Agriculture (USDA) Soil Taxonomy and correlated with the World Reference Base for soil resources system.

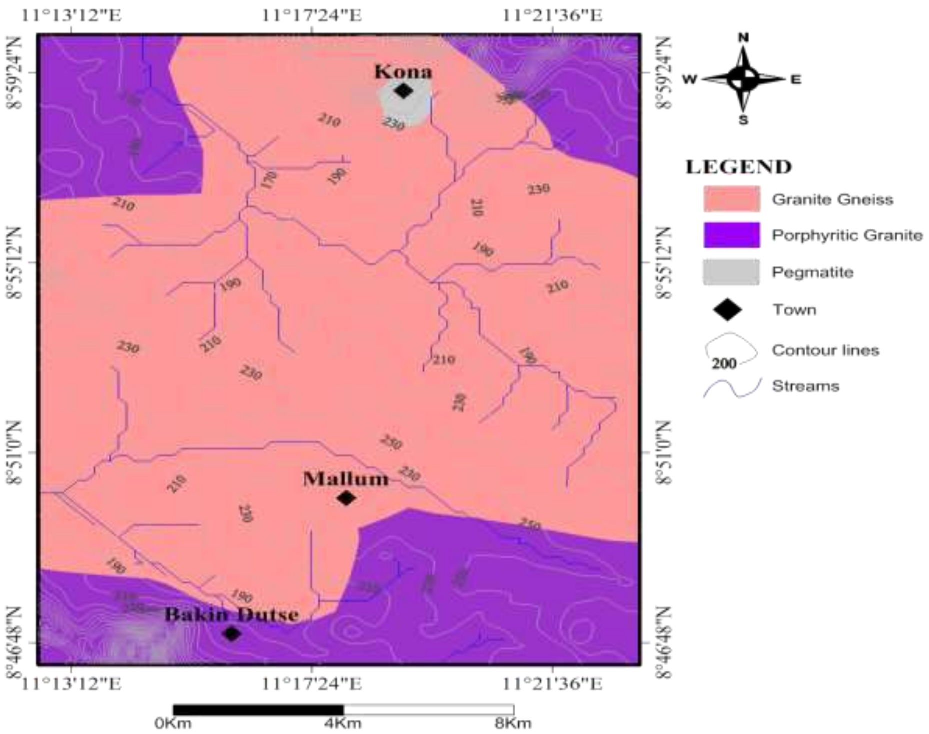

Figure 1: Map of the study sites

Soil Fertility Capability Classification Procedures

Data obtained from field morphological study and laboratory analyses of soil samples from the 12 pedon were used for the soil fertility capability classification. The conversion data used in evaluating the soils are as outlined by Sanchez *et al.* (1982; 2003). The system consists of three categorical levels, namely, 'type', (texture of plough layer or top 20.00 cm), 'substrata type' (texture of subsoils) and 'modifiers' (soil properties or conditions which act as constraints to crop performance). Class designations from the three categorical levels are combined to form an FCC unit.

Three levels of classification in the scheme: type, substrata type and modifier (Sanchez *et al.,* 1982; 2003). The type corresponds to the highest category and is determined by the average texture of the plough layer or the upper 20.00 cm of soil. The USDA system of soil textural classes are used, and the field determination of texture could be deemed sufficient in the absence of an analytical determination (Soil Science Division Staff, 2017). The substrata type is the average texture of the subsurface/subsoil assessed at the depth of 20.00 to 50.00 cm. It is used wherever the texture of the subsurface differs from the texture of the surface soil within the defined limit of depth (20.00-50.00 cm); otherwise the name of this category shall not appear. For example, a loamy sand soil within horizons at 20.00 to 50.00 cm shall be classified as substrata S; whereas a similar soil with the clay horizon at 20.00 to 50.00 cm shall be classified as type C. Modifiers are chemical or physical properties of soil relating to its arable layer or section more shallow than 20.00 cm. These properties signify fertility limitations with different interpretations, and are represented by small letters. The modifiers and their meanings are reported in Sanchez *et al*. (1982; 2003).

RESULTS AND DISCUSSION

Soil Properties

Sand dominated the particle size fractions of the soils developed over the three parent materials and constituted > 700.00 g kg^{-1} (Table 1), resulting in dominantly loamy sand and sandy loam textures with few sandy clay loam textures. Sand was previously reported to dominate soils developed on basement complexes (Sadiq *et al.,* 2021), and this dominance over the clay and silt particles was attributed to the

Table 1: Physical and chemical properties of soils of the study area

Soil Unit	Horizon	Depth (cm)	Clay	Silt	Sand	TC	Soil pH
			g kg^{-1}				
			Porphyritic granite (PG)				
PGCP	Ap	0.00-20.00	100.00	90.00	810.00	LS	6.20
	Btv	20.00-81.00	180.00	70.00	750.00	SL	5.80
	Bt	81.00-128.00	140.00	70.00	790.00	SL	6.60
	CCv	128.00-175.00	120.00	70.00	810.00	SL	6.70
PGUS	Ap	0.00-12.00	120.00	70.00	810.00	SL	6.90
	CB	12.00-62.00	80.00	70.00	850.00	LS	6.50
	C	62.00-126.00	80.00	50.00	870.00	LS	6.90
PGMS	Ap	0.00-21.00	80.00	110.00	810.00	SL	6.30
	Btv	21.00-60.00	140.00	190.00	670.00	SL	6.90
PGLS	Apg	0.00-10.00	100.00	90.00	810.00	LS	6.00
	Cgcv	10.00-15.00	100.00	70.00	830.00	LS	6.20
			Pegmatite (PT)				
PTCS	Apg	0.00-12.00	100.00	90.00	810.00	LS	6.60
	ABg	12.00-38.00	80.00	50.00	870.00	LS	6.30
	Btg	38.00-63.00	220.00	290.00	490.00	SCL	6.30
	CBg	63.00-123.00	180.00	210.00	610.00	SL	6.40
	C	123.00-159.00	120.00	210.00	670.00	SL	7.30
PTUS	Apg	0.00-39.00	100.00	90.00	810.00	LS	5.90
	Btg	39.00-82.00	180.00	90.00	730.00	SL	6.20
	Cg	82.00-125.00	180.00	110.00	710.00	SL	6.30
PTMS	Apg	0.00-37.00	140.00	130.00	730.00	SL	5.70
	Btg1	37.00-66.00	240.00	230.00	530.00	SCL	6.30
	Btg2	66.00-120.00	180.00	150.00	770.00	SL	5.50
PTLS	Apg	0.00-23.00	100.00	50.00	870.00	LS	5.40
	Btg1	23.00-89.00	80.00	70.00	850.00	LS	5.80
	Btg2	89.00-100.00	80.00	70.00	850.00	LS	7.20
	C	100.00-157.00	80.00	50.00	870.00	LS	6.60
			Granite gneiss (GG)				
GGCS	Ap	0.00-12.00	100.00	70.00	830.00	LS	6.70
	B	12.00-36.00	120.00	90.00	790.00	LS	6.40
	C	36.00-152.00	220.00	70.00	710.00	SCL	6.60
GGUS	A	0.00-30.00	80.00	70.00	850.00	LS	7.10
	B	30.00-80.00	100.00	90.00	810.00	LS	7.50
	C	80.00-155.00	100.00	70.00	830.00	LS	7.40
GGMS	Ap	0.00-16.00	80.00	50.00	870.00	LS	6.50
	AB	16.00-56.00	140.00	70.00	790.00	SL	6.60
	Btv	56.00-134.00	140.00	210.00	650.00	SL	6.80
	C	134.00-185.00	180.00	210.00	610.00	SL	7.30
GGLS	Ap	0.00-18.00	80.00	50.00	870.00	LS	6.20
	Ccv	18.00-40.00	80.00	50.00	870.00	LS	6.70

TC - Textural class, LS - Loamy Sand, SL - Sandy Loam, SCL - Sandy Clay Loam; PG - porphyritic granite, PT - pegmatite, GG - granite-gneiss; CP - crest, US - upper slope, MS - mid slope, LS - lower slope granitic origin of the complex (Maniyunda, 2012; Shobayo, 2019). Soil texture is an important criteria for FCC, such that soil texture alongside drainage have been used as criteria for the creation of agroecological units in the beach sands area of Akwa Ibom State (Udoh and Ibia, 2022). Soil pH (H_2O) varied between 5.40 and 7.40 (Table 1), and was rated as strongly acid to slightly alkaline. However, most of the soils were between moderately acid to neutral condition. The pH values relate to the findings of Maniyunda (1999), Odunze (2006) and Shobayo (2010) on basement complex soils. They opined that strongly acid to slightly alkaline pH range could partly be due to the chemical nature of the underlying parent material and also partly due to the leaching of soluble salts.

Table 2 shows that soil organic carbon (OC), total nitrogen (TN) and available phosphorus (avail. P) were generally low with ranges of 0.24-17.67 (mean, 3.20) 0.003-0.28 (mean 0.05) and 0.92-15.86 (mean 3.66) g kg^{-1}, respectively. Some researchers (Ezenwa and Esu, 1999; Jaiyeoba, 2003; Odunze and Kureh, 2009; Eche *et al*., 2014; Aliyu *et al*., 2016) in the northern Guinea Savannah noted that these low levels were due to high temperature and associated high organic matter mineralisation in the area. They, however, reported that the highest contents are at the surface soils which they attributed to the deposition of biomass on soil surfaces. This is re-confirmed in this work. The low values also contributed to the low to medium effective cation exchange capacity (ECEC) recorded (mean, 4.5 cmol kg^{-1}).

The Low ECEC is attributed to the high sand content of the soils (Ukabiala *et al*., 2021), dominated by the fine sand fraction (Obalum *et al.,* 2012), and this led to the leaching of exchangeable bases, OC and TN. The low ECEC could also be attributed to the extensive and continuous cultivation of the soils (Kolo *et al*., 2022). In this case, the soil may have been depleted of its plant nutrients, without any plan to replenish the nutrients. The values were generally an indication of low nutrient retention of the soil, as reported by previous findings. Surface horizon of soils on upper slope of GG recorded moderate content of available P (15.86 mg kg^{-1}), and this was attributed to the residual effect of late fertilizer application.

Table 2: Chemical properties of soils of the study area

Soil unit	Horizon	Depth (cm)	OC	TN	Avail. P	Exchangeable cations				EA	ECEC
						Ca	Mg	K	Na		
			g kg⁻¹			cmol(+) kg⁻¹					
			Porphyritic granite (PG)								
PGCP	Ap	0.00-20.00	3.75	0.01	0.93	2.31	1.05	0.05	0.20	0.26	3.87
	Btv	20.00-81.00	3.75	0.01	0.92	3.99	1.00	0.05	0.10	0.13	5.27
	Bt	81.00-128.00	3.75	0.00	0.93	3.49	0.30	0.13	0.20	0.15	4.27
	CCv	128.00-175.00	0.75	0.01	0.98	3.24	0.20	0.12	0.10	0.16	3.82
PGUS	Ap	0.00-12.00	10.13	0.01	0.93	5.91	0.04	0.09	0.20	0.30	6.54
	CB	12.00-62.00	2.63	0.01	0.94	3.45	1.00	0.11	0.10	0.16	4.82
	C	62.00-126.00	0.75	0.01	0.93	2.21	1.00	0.11	0.10	0.20	3.62
PGMS	Ap	0.00-21.00	13.15	0.02	5.60	4.54	0.02	0.12	0.60	0.29	5.57
	Btv	21.00-60.00	2.47	0.01	6.53	2.72	1.00	0.10	0.20	0.20	4.22
PGLS	Apg	0.00-10.00	8.63	0.01	1.87	3.06	1.00	0.11	0.10	0.25	4.52
	Cgcv	10.00-15.00	1.88	0.01	1.90	1.07	1.60	0.14	0.10	0.01	2.92
			Pegmatite (PT)								
PTCS	Ap	0.00-12.00	14.39	0.02	6.53	2.40	0.40	0.19	0.15	1.80	4.94
	ABg	12.00-38.00	3.70	0.01	5.60	1.24	0.50	0.15	0.18	1.00	3.07
	Btg	38.00-63.00	3.70	0.01	4.66	1.77	1.00	0.15	0.15	2.20	5.27
	CBg	63.00-123.00	2.47	0.01	3.73	1.35	0.40	0.17	0.10	2.00	4.02
	C	123.00-159.00	1.23	0.01	3.73	1.70	0.60	0.20	0.12	1.80	4.42
PTUS	Ap	0.00-39.00	8.95	0.00	3.73	1.40	0.60	0.30	0.41	2.80	5.51
	Btg	39.00-82.00	3.66	0.01	5.60	3.30	0.60	0.25	0.12	1.40	5.67
	Cg	82.00-125.00	0.81	0.00	5.60	1.83	0.80	0.27	0.11	1.40	4.41
PTMS	Ap	0.00-37.00	1.01	0.01	3.73	1.41	1.00	0.18	0.15	1.60	4.34
	Btg1	37.00-66.00	0.60	0.00	1.87	3.23	0.70	0.17	0.60	1.60	6.30
	Btg2	66.00-120.00	0.33	0.01	1.87	2.44	1.00	0.28	0.15	1.40	5.27
PTLS	Apg	0.00-23.00	17.67	0.01	2.80	1.78	0.95	0.17	0.26	1.60	4.76
	Btg1	23.00-89.00	2.06	0.01	2.01	1.42	0.80	0.30	0.10	1.20	3.82
	Btg2	89.00-100.00	0.33	0.01	1.98	0.90	0.80	0.15	0.22	0.80	2.87
	C	100.00-157.00	2.39	0.01	0.93	0.87	0.80	0.16	0.19	1.40	3.42
			Granite gneiss (GG)								
GGCS	Ap	0.00-12.00	1.67	0.11	7.46	2.45	1.00	0.19	0.10	1.60	5.34
	B	12.00-36.00	0.47	0.07	2.80	1.61	0.60	0.15	0.11	1.40	3.87
	C	36.00-200.00	0.43	0.07	0.93	2.14	1.00	0.15	0.18	2.20	5.67
GGUS	A	0.00-30.00	1.05	0.21	15.86	3.85	1.00	0.19	0.15	1.20	5.34
	B	30.00-80.00	0.32	0.06	4.66	3.85	0.60	0.30	0.12	1.20	6.07
	C	80.00-155.00	0.28	0.06	4.66	2.96	0.40	0.15	0.11	1.20	4.82
GGMS	Ap	0.00-16.00	0.61	0.28	4.66	1.20	0.60	0.17	0.13	1.40	3.50
	AB	16.00-56.00	0.24	0.24	4.66	1.17	0.40	0.15	0.30	1.20	3.22
	Btv	56.00-134.00	0.30	0.18	3.73	1.10	0.60	0.19	0.12	1.20	3.21
	C	134.00-185.00	0.30	0.21	2.80	1.53	1.00	0.18	0.10	1.20	4.01
GGLS	Ap	0.00-18.00	0.78	0.09	4.45	1.20	0.60	0.18	0.14	1.00	3.12
	Ccv	18.00-40.00	0.28	0.06	0.86	2.00	1.00	0.15	0.21	1.20	3.42

PG - porphyritic granite, PT - pegmatite, GG - granite-gneiss; CP - crest, US - upper slope, MS - mid slope, LS - lower slope;
OC - organic carbon, TN - total nitrogen, avail. P - available phosphorus, EA - exchangeable acidity, ECEC - effective cation exchange capacity

Table 3: Soil fertility capability classification for soils of the study areas

Pedon/type	Type	Sub type	Condition modifiers					SFCC unit			Interpretation		Management options
			*	d	k	e	a	n	m	g			
Porphyritic granite (PG)													
PGCP	S	L	-	+	-	+	+	-	+	-	SLdeam (12-18%)	Sandy topsoil and loamy subsoil, dry, low CEC, aluminium toxicity, and low organic carbon on 12-18% slope landscape.	Application of appropriate fertilizer, liming and organic matter. Irrigation during dry season and contour ridging.
PGUS	L	S	-	+	-	-	+	-	+	-	LSdkam (4-7%)	Loamy topsoil and sandy subsoil, dry, low K, aluminium toxicity, and low organic carbon. Soils on 4-7% slope topography.	Application of appropriate fertilizer, liming and organic matter. Irrigation during dry season.
PGMS	L	L	-	+	-	-	+	-	+	-	Ldam (4-7%)	Loamy top and sub soils, dry, aluminium toxicity, and low organic carbon on 4-7% slope landscape.	Application of appropriate fertilizer, liming and organic matter. Irrigation during dry season.
PGLS	S	S	-	-	-	-	+	-	+	+	Samg (2-4%)	Sandy surface and subsurface, aluminium toxicity, low organic carbon, and poorly drained condition.	Application of appropriate fertilizer, liming and organic matter. Contour ridging and drainage canals.
Pegmatite (PT)													
PTCS	S	S	-	+	-	-	+	-	+	+	Sdamg (4-7%)	Sandy top and sub soils, dry, aluminium toxicity, low organic carbon, and poorly drained condition on 4-7% slope landscape.	Split fertilizer application, liming and organic matter. Contour ridging and drainage canals. Irrigation during dry season.
PTUS	S	L	-	+	+	-	-	-	+	+	SLdkmg (2-4%)	Sandy top and loamy subsoil, dry, K deficiency, low organic carbon, and poorly drained condition.	Application of appropriate fertilizer, and organic matter. Contour ridging and drainage canals. Irrigation during dry season.
PTMS	L	L	-	+	-	-	+	-	+	+	Ldamg (2-4%)	Laomy top and sub soils, dry, aluminium toxicity, low organic carbon, and poorly drained condition.	Application of appropriate fertilizer, liming and organic matter. Contour ridging and drainage canals. Irrigation during dry season.
PTLS	S	S	-	+	-	-	+	-	+	+	Sdamg (2-4%)	Sandy top and sub soils, dry, aluminium toxicity, low organic carbon, and poorly drained condition	Organic matter, liming and split fertilizer application. Contour ridging and irrigation during dry season.
Granite gneiss (GG)													
GGCS	L	S	-	+	-	-	+	-	+	-	Sdam (0-2%)	Sandy top and sub soils, dry, aluminium toxicity, and low organic carbon on nearly flat land.	Application of appropriate fertilizer, liming and organic matter. Irrigation during dry season.
GGUS	S	S	-	+	-	-	-	-	+	-	Sdm (0-2%)	Loamy top and sub soils, dry, and low organic carbon on level to nearly level land.	Split fertilizer application, organic matter, and irrigation during dry season.
GGMS	S	L	-	+	-	+	+	-	+	-	SLdeam (7-12%)	Sandy topsoil and loamy subsoil, dry, low CEC, aluminium toxicity, and low organic carbon on 12-18% slope landscape.	Split fertilizer application, liming and organic matter. Irrigation during dry season and contour ridging.
GGLS	S	S	-	+	+	+	+	-	+	-	Sdkeam (12-18%)	Sandy top soil and subsoil, dry, K deficiency, aluminium toxicity, and low organic carbon. Soils on steep (12-18%) slope.	Split fertilizer application, liming and organic matter. Irrigation during dry season and contour ridging.

* - high gravel content, d - dry (ustic soil moisture regime), k - low K reserves, e - low CEC, a - aluminium toxicity (exch. acidity > 60% Al saturation), n - sodium (ESP > 15%), m - low organic carbon, g - gleying or aquic soil moisture regime; PG - porphyritic granite, PT - pegmatite, GG - granite-gneiss; CP - crest, US - upper slope, MS - mid slope, LS - lower slope; S - Sand, L - Loam

Taxonomic Classification of the Soils

Taxonomic soil classification was performed based on the criteria of the USDA and correlated with the World Reference Base for soil resources system. The summary of classifications is shown in Table 4. At the soil order category, irrespective of lithology, the pedons located at the crest (PGCP and PTCS) and upper slope positions (PGUS and PTUS) qualified as Ultisols except for soils in the crest and upper slope overlying granite-gneiss that qualified as Inceptisols (GGCS and GGUS). Pedons located in the middle and lower slopes were either classified as Entisols or Inceptisols. In the World Reference Base for soil resources system, all the soils were either qualified as Haplic Acrisols, Dystric Gleysols or Haplic Acrisols.

Fertility Capability Classification (FCC) of the Soils

The FCC units for the various soils on the basement complexes are shown (Table 3). Low gravel content and exchangeable sodium characterized soils across the lithologies. Ustic soil moisture regime, exchangeable acidity (aluminium toxicity) and low OC were the major limiting factors to fertility capability of the soils on the different basement complexes (Table 3). Ustic soil moisture regime may restrict rainfed crop production to a season per annum, except irrigated agriculture is introduced in the area to increase crop production. This may constitute a major set-back to the overall turn-over per annum. Low available P in the soils may have been as a result of P-fixation. Aluminium toxicity causes P-fixation, and reduces its availability for crop uptake. Hence, P should be applied close to plant roots alongside organic matter at recommended doses. This way, it will be adsorbed and released when it is required for plant uptake. The generally low OC content of the soils implies that nutrient content, moisture retention and aeration will be retarded (Brady and Weil, 2005). These may, however, be sourced from crop residue, farm yard manure, green manure and compost (Odunze, 2017). Therefore, the rate of leaching is expected to increase if the low OC content is not addressed.

The assessment of FCC at the type and substrata type levels showed that soils on porphyritic granite lower slope (PGLS), pegmatite crest (PTCP), pegmatite lower slope (PTLS), granite gneiss upper slope (GGUS) and granite gneiss lower slope (GGLS) were of sandy texture within the top 50 cm (Table 3). Loam dominated soils on PG (mid slope), PT(mid slope) and GG (crest), while the rest were characterized mostly by sand and loamy type and substrata (Table 3).

The FCC rated the soils on PG (crest) and GG (mid slope) as SLdeam as the soils belong to sandy type and loamy substrata. The soils condition modifiers included ustic soil moisture regime (d) which is likely to reduce available water supply, low ECEC (e), aluminum toxicity (a) and low OC (m). Other soils that indicated similarity in their assessment were PGMS and GGCS showing Ldam. It implied loamy type and substrata characteristics with limiting condition modifier including d, a and m. Hence, management practices for their sustainable use will be similar. Likewise, soils on PTCP and PTLS were classified as Sdamg. This implies sandy type and substrata type and were restricted by d, a, m and g (Table 3). Soils of PTMS had similar limitations, but were characterized by loamy group of texture. Soils developed on PT were limited by d, m and g. Poor drainage condition modifier associated with PT tends to restrict suitability for the choice of crops to those tolerating excess water such as rice and sugar cane. Construction of drains and ridge cultivation are expected to improve soil drainage condition. Soil drainage is an important soil property in FCC as Udoh and Ibia (2022) has used it as a criteria for agroecological units zoning in the beach sand area of Akwa Ibom State (Udoh and Ibia, 2022).

Soils on PGUS, PGLS, GGUS and GGLS had variation in FCC compared to the other soils due to texture, e and k, and were rated as LSdkam, Samg, Sdm and Sdkeam, respectively. Soils on PTLS had more limitations compared to other soils in the study area. Hence, management practice required for their sustainable use will differ.

CONCLUSION

The soils developed on porphyritic granite, pegmatite and granitic gneiss parent materials showed ustic soil moisture regime, exchange acidity and low organic carbon as dominant fertility capability classification limitations. The introduction of irrigated agriculture, the use of organic and mineral fertilizers are expected to improve crop productivity and improve the fertility capability of the soils for the sustainable production of a wider range of crops. The poor drainage condition associated with soils at the lower landscape positions along the pegmatite toposequence is most likely to limit the suitability of the soils to rice and sugar cane cultivation. However, with appropriate drainage techniques and structures, a wider range of crops may be accommodated.

Table 4: Summary of Taxonomic classification of the studied soils

Pedon	Order	Suborder	Great group	Subgroup	WRBSR
PGCP	Ultisols	Ustults	Haplustults	Haplic Haplustults	Haplic Acrisols
PGUS	Ultisols	Ustults	Haplustults	Haplic Haplustults	Haplic Acrisols
PGMS	Entisols	Aquents	Psamments	Typic Ustipsamments	Dystric Gleysols
PGLS	Entisols	Aquents	Psamments	Typic Ustipsamments	Dystric Gleysols
PTCS	Ultisols	Ustults	Haplustults	Typic Haplustults	Haplic Acrisols
PTUS	Ultisols	Ustults	Haplustults	Typic Haplustults	Haplic Acrisols
PTMS	Inceptisols	Ustepts	Dystrustepts	Typic Dystrustepts	Haplic Arenosols
PTLS	Entisols	Aquents	Psamments	Typic Ustipsamments	Dystric Gleysols
GGCS	Inceptisols	Ustepts	Dystrustepts	Typic Dystrustepts	Haplic Arenosols
GGUS	Inceptisols	Ustepts	Dystrustepts	Typic Dystrustepts	Haplic Arenosols
GGMS	Ultisols	Ustults	Haplustults	Typic Haplustults	Haplic Acrisols
GGLS	Ultisols	Ustults	Haplustults	Typic Haplustults	Haplic Acrisols

PG - porphyritic granite, PT - pegmatite, GG - granite-gneiss; CP - crest, US - upper slope, MS - mid slope, LS - lower slope

REFERENCES

Ajeigbe H.A. and Singh B.B. (2010). Improved cowpea-cereal cropping systems: Cereal double cowpea system for northern Guinea Savanna zone. IITA, Ibadan, p. 17.

Aliyu J., Malgwi W.B., Jimoh I.A., Shobayo A.B. and Ibrahim M.M. (2016). Suitability assessment of surface water for irrigation in Galma floodplain, Zaria, Kaduna State, northwestern Nigeria. *J. Sci. Res. Rep.,* **10 (7),** 1-9

Brady N.C. and Weil R.C. (2005). *The Nature and Properties of Soils* (13th edn.). Pearson Printice-Hall Inc., India, 881 pp.

Bray R.H. and Kurtz L.T. (1945). Determination of total organic and available forms of phosphorus in soils. *Soil Sci.,* **59,** 39-45

Bremner J.M. and Mulvaney C.S. (1982). Nitrogen-total. In: Page A.L., Miller R.H. and Keeney D.R. (eds.), *Methods of Soil Analysis Part 2* (pp. 595-624). Agron. No. 9, Madison WI

Eche N.M., Amapu I.Y., Bruns M.A., Odunze A.C. and Uyovbisere E.O. (2014). Fertility management effects on soil physical and chemical properties under long-term maize cropping in an Alfisol in Northern Guinea Savanna zone. *Nig. J. Soil Sci.,* **24 (1),** 134-146

Ezenwa M.I.S. and Esu I.E. (1999). A pedological study of soils derived from precambrian basement complex rocks in the Guinea Savanna area of Nigeria. *Samar. J. Agric. Res.,* **15,** 231-239

Foli S. (2012). *Farm Characterisations in the Southern and Northern Guinea Savannah Zones Of Nigeria*: *Identification of Niches For Grain Legume Technologies*. MSc., Plant Prod. Sys., Wageningen Univ., 67 pp.

Harris F.M.A. (1998). Farm-level assessment of the nutrient balance in northern Nigeria. *Agric. Ecosys. Environ.,* **71 (1-3),** 201-214

Hoffmann I. and Gerling D. (2001). Farmers' management strategies to maintain soil fertility in a remote area in north-west Nigeria. *Agric. Ecosys. Environ.,* **86 (3),** 263-275

Ibia T.O. and Udo E.J. (2009). *Guide to Fertilizer Use for Crops in Akwa Ibom State, Nigeria*. Sibon Bks Ltd, Lagos

Jaiyeoba I.A. (2003). Changes in soil properties due to continuous cultivation in Nigerian semi-arid savannah. *Soil Till. Res.,* **70,** 91-98

Kefas P.K. (2021). *Pedogenesis and Fertility Capability Classification of Selected Soils of Varying Parent Materials in Northern Guinea Savanna, Taraba State, Nigeria.* PhD Thesis, Department of Soil Science, University of Nigeria, Nsukka, Nigeria, 166 pp.

Kolo J., Ukabiala M.E., Osakwe U.C., *et al.* (2022). Overlooked influence of Indian Hemp (*Cannabis sativa*) cultivation on soil physicochemical fertility of humid tropical agroecosystems: Upland soils. *Indian J. Ecol.*, **49 (4),** 1391-1396. https://doi.org/10.55362/IJE/2022/3676

Lin C.F. (1989). Fertility capability classification of Taiwan soils. In: *Classification and Management of Rice Growing Soils*. FFTC Book Series, No.39 Proc. 5th Int. Soil Manage. Workshop, pp. 80-90

Maclean E.O. (1982). Aluminium. In: Black C.A. (ed.), *Methods of Soil Analysis Part 2* (pp. 199-224). Agron. No. 9, Am. Soc. Agron., Madison Wisconsin, USA

Maniyunda L.M. (1999). *Pedogenesis on Loess and Basement Complex Rocks in a Sub Humid Environment of Nigeria and the Suitability of the Land for Rainfed Cultivation*. MSc Thesis, Ahmadu Bello University, Zaria, Nigeria, 108 pp.

Maniyunda L.M. (2012). *Pedogenesis of a Lithosequence in the Northern Guinea Savanna of Kaduna State, Nigeria*. PhD Thesis. Department of Soil Science, Ahmadu Bello University, Zaria, Nigeria, 145 pp.

NIMET (2009). Nigeria meteorological station, Yola International Airport, Nigeria, 18 pp.

Obalum S.E., Nwite J.C., Watanabe Y., Igwe C.A. and Wakatsuki T. (2012). Comparative topsoil characterization of *sawah* rice fields in selected inland valleys around Bida, north-central Nigeria: physicochemical properties and fertility status. *Trop. Agric. Dev.,* **56 (2),** 39-48. https://doi.org/10.11248/jsta.56.39

Odunze A.C. (2006). Soil properties and management strategies for some sub-humid savanna zone Alfisols in Kaduna State, Nigeria. *Samaru J. Agric. Res.,* **22,** 3-14

Odunze A.C. and Kureh I. (2009). Land Use limitations and management option for a Savanna Zone Alfisol. *J. Agric. Environ. Int. Dev.,* **103 (4),** 321-335

Odunze A.C. (2017). Healthy soil: The key to agricultural revolution in Nigeria. An Inaugural Lecture Series 04/17, Ahmadu Bello University, Zaria, 54 pp.

Sadiq F.K., Maniyunda L.M., Adegoke K.A. and Anumah A.O. (2021). Evaluating quality of soils formed on basement complex rocks in Kaduna State, northern Guinea savanna of Nigeria. *Environ. Monit. Assess.,* **193,** 383. https://doi.org/10.1007/s10661-021-09157-0

Sanchez P.A., Couto W. and Buol S.W. (1982). The fertility capability, classification system: Interpretation, applicability and modification. *Geoderma,* **27,** 283-309

Sanchez P.A., Shepherd K.D., Soule M.J., *et al.* (2003). Soil fertility replenishment in Africa: An investment in natural resource capital. In: Buresh R.J., Sanchez P.A. and Calhoun F. (eds.), *Replenishing Soil Fertility in Africa*. https://doi.org/10.2136/sssaspecpub51.c1

Schoeneberger P.J., Wysocki D.A., Benham E.C. and Soil Survey Staff (2012). Field book for describing and sampling soils, Ver 3.0. Natural Resour. Conserv. Serv., National Soil Survey Center, Lincoln, NE, 300 pp.

Shobayo A.B. (2010). *A Lithosequence of Soils Developed on Basement Complex Rocks of Zaria, the Northern Guinea Savanna, Nigeria*. MSc Thesis, Ahmadu Bello University Zaria, Nigeria, 57 pp.

Shobayo A.B. (2019). Taxonomic and land capability classifications of some Nigerian northern guinea savanna soils. *J. Crop Res. Agrofor. Environ.,* **3,** 83-103

Smith N.O., Maclean I., Miller F.A. and Carruthers S.R. (1997). Crops for industry and energy in Europe. Univ. of Reading, European Commision, Directorate General XII E-2, Agro-Industrial Research Unit

Soil Science Division Staff (2017). Soil survey manual. In: Ditzler C., Scheffe K. and Monger H.C (eds.), USDA Handbook 18. Govt. Printing Office, Washington DC

Soil Survey Staff (2014). *Keys to Soil Taxonomy* (12th edn.). United States Dept. of Agric., Washington DC, 360 pp.

Udoh B.T., Ogunkunle A.O. and Akpan U.S. (2013). Fertility capability classification of acid sands (soils) as influenced by parent materials in Akwa Ibom State, Nigeria. *Nig. J. Soil Sci.,* **23 (1),** 56-66

Udoh B.T. and Ibia T.O. (2022). Fertility capability classification for agricultural land use planning in the beach sands area of Akwa Ibom State, Nigeria. *Agro-Science,* **21 (2),** 74-78. http://dx.doi.org/10.4314/as.v21i2.8

Udo E.J., Ibia T.O., Ogunwale J.A., Ano A.O. and Esu I.E. (2009). *Manual of Soil, Plant and Water Analysis*. Sibon Books Limited, Lagos Nigeria, 183 pp.

Ukabiala M.E., Kolo J., Obalum S.E., Amhakhian S.O., Igwe C.A. and Hermensah. (2021). Physicochemical properties as related to mineralogical composition of floodplain soils in humid tropical environment and the pedological significance. *Environ. Monit. Assess.* **(2021) 193:**569. https://doi.org/10.1007/s10661-021-09329-y

Walkley A. and Black T.A. (1934). An examination of digestion Jarett method for determining soil organic matter and proposed modification of the chromic acid titration method. *Soil Sci. Soc. Am. J.,* **37,** 29-38. http://dx.doi.org/10.1097/00010694-193401000-00003

World Reference Base for Soil Resources by ISSS-ISRIC-FAO (2014). World Soil Resources Report No. 106. Food & Agric. Org. (FAO), Rome Italy, 203 pp.