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Characterization and Classification of Soils Derived from Two Different Parent Materials in Niger State, Nigeria

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ABSTRACT

The aim of this study was to characterize and classify soils developed under two different parent materials (that is, basement complex rocks and the sedimentary rocks) in Niger State. Four sites, two each under the formations were selected for the study. Gidan Mangoro (GDM) and Nubwa Koyi (NBK) represented the basement complex while Patita (PTA) and Ndayako (NDY) represented the sedimentary rocks. In each site, a mini profile pit (1m x 1m x 1m) was dug, described and sampled according to FAO guidelines. The samples were analyzed in the laboratory following the standard analytical procedures. The soils were classified according to USDA Soil Taxonomy system and correlated with the WRB System. The texture of GDM, was loamy sand at topmost horizon (Ap), underlain by sandy clay loam at Bt horizon over sandy loam texture at Btv horizon. The NBK was sandy loam at Ap horizon over sandy clay loam at Btv1 and Btv2 horizons. PTA, and NYK were sandy loam all through. Soil pH was moderately acid to neutral in all the study sites. Total nitrogen was low (0.3 g kg-1), (> available phosphorus was moderate to high (9.33 to 29 mg/kg-1) Exchangeable potassium (K) was low to very low (0.05 to 0.11 cmol kg-1), while cation exchange capacity (CEC) ranged from 5.02 to 10.40 cmol kg-1 and was low to moderate. The soils were classified as Typic Plinthustalf (GDM),Plinthic Kanhaplustult (NBK), Oxic Haplustept (PTA) and Rhodic Kanhaplustults (NDY). The soils developed under basement complex rocks were shallow to deep soils while the soils from sedimentary rocks formations were deep to very deep.

1. Introduction

Soil characterization is the separation of soils into groups of similar morphological properties such as colour, texture, structure, consistency, roots; physical properties such as sand, silt, clay, bulk density, porosity; chemical properties such as pH, organic matter content, total nitrogen, available phosphorus and exchangeable cations (Ukut et al., 2014).

Soil classification is the systematic grouping or separation of soils base on their properties. There is an increasing demand for information on soils to produce food (Fasina et al 2007). Soil characterization, classification and evaluation are the first or primary indicators for establishing soil database, as proper understanding of soil resources for a judicious use of land resources (Jagdish et al. 2009). Parent

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materials have an influence on soil morphological, physical and chemical properties and affects the pattern of soil distribution over landscape even when the soils are formed from the same parent material Lawal el al., (2014). Productivity of a soil is a function of its physical and chemical properties. These properties are as a result of the interaction among the soil forming factors and processes, hence, making soil to be heterogeneous (Lawal et al., 2014).

The objective of this study was to characterize and classify soils developed under two geological formations (that is, basement complex rocks and the sedimentary rocks) in Niger State, Nigeria, for proper utilization.

2. Literature review

Soil characterization presents a potent resource for benefits to man in this regard, essentially in the theme of food sustainability and environmental protection (Esu, 2004). It is also concerned with the determination of soil morphological properties, as well as their fitting into generally accepted soil classification system. Characterization provides the building block for understanding and appreciating the soil, and further classification of it. Soil characterization provides the fundamental information necessary to create functional soil classification schemes and assess soil fertility to resolve some unique soil problems in an ecosystem (Lekwa et al., 2004). Soil classification is the systematic grouping or separation of soils based on their morphological properties (Fasina et al., 2007). Soil classification group soils according to their order of characteristics under given set of physical conditions. Soils with similar characteristics and behaviour are usually put into similar groups of a soil classification system. The classification is usually based on soil properties defined in terms of diagnostic horizons, properties and materials, which should mostly be measurable and observable in the field (FAO, 2018).

3. Materials and Methods

Niger State is underlain by two geological terrains namely the Basement complex rocks and the sedimentary rock formations. The study covered four sites, two from the basement complex and two from sedimentary rock geological formation. The sites were Gidan Mangoro in Bosso (Longitude: 6^{o} 29′ 30.570″ E and Latitude: 9^{o} 34′ 29.652″ N,). Nubwa koyi in Suleja (Longitude: 7^{o} 08′ 43.428″ E and Latitude: 9^{o} 15′ 08.826″ N,). Patita in Gbako (Longitude: 5^{o} 53′ 10.835″ E and Latitude: 9^{o} 12′ 22.716″ N,). Ndayako in Mokwa (Longitude: 5^{o} 00′ 49.440″ E and Latitude: 9^{o} 22′ 19.002″ N,), all within the southern Guinea savanna agroecological zone of Nigeria. Niger State is sub-humid tropical and experiences two distinct wet season and dry seasons. Rainfall is bimodal with mean total annual rainfall of 1,600 mm in the southern part and decreased to 1,200 mm in the northern part of the state, distributed from the months of May to October. The dry season is about 5 month’s duration from November to March. The mean annual maximum rainfall is about 1600 mm. The average minimum and maximum temperatures are 20 ℃ and 37 ℃ respectively while the mean annual relative humidity is between 39% to 70%. Geomorphologically, Niger State was characterized by undulating landscape, upland, lowland, plains, flood plains, and rolling dissected plains (Alabi 2011).

Field work and soil sampling

One profile pit measuring 1 m × 1 m × 1 m (or to permissible depth), was dug in each of the locations and were described according to FAO guidelines (FAO, 2006). Soil samples were collected from the identified genetic horizons, from bottom to the top of the profile. The following materials were used for the field study; handheld GPS device, Munsell Colour Chart (2009 version), a plastic bucket, zip-lock bags, digger, shovel, hand-trowel, hand notebook, writing pen, permanent marker, stapler, and masking tape. The well-labelled soil samples were taken to the laboratory for processing and routine analysis.

Laboratory Analysis

The air-dried soil samples were passed through a 2 mm mesh and analysed according to standard laboratory procedures (IITA, 2015). Briefly, particle size distribution was determined by Bouyoucos hydrometer method, using sodium hexametaphosphate as the soil dispersing agent. The textural classes of the soils were determined using IUSS soil textural triangle. Soil pH was determined in a 1:2.5 soil / water suspension using a standard pH meter and electrodes. Exchangeable acidity (H+ and Al3+) was determined by titrimetric method, while organic carbon (C) was determined by Walkley-Black method of wet combustion involving oxidation of organic matter with potassium dichromate (K2Cr2O7) and sulphuric acid (H2SO4). Exchangeable bases (Ca, Mg, K and Na) were extracted with 1N NH4OAc. Calcium and Mg in the soil extract were determined using atomic absorption spectrophotometers while K and Na were determined by flame photometry. Cation exchange capacity (CEC) was determined by the neutral 1N NH4OAc saturation method. Base saturation was determined by calculation, dividing the sum of exchangeable bases by their CEC and then multiplied by 100.

4. Results and discussions

Morphological Properties of the Soils

The study showed that the soils from GDM and NBK were moderately-deep to deep, having 70-100 cm effective soil depth, with coarse fragments. The dominant colour spectral of the soils indicated a range of 7.5YR and 10YR hues which impacted the soils with colour variations such as dark yellowish brown, strong brown, brown, pale brown. According to Brady and Weil (1999) and Aki et al. (2014), these groups of colours may be indicative of the presence of migmatite, gibbsite, goethite and haematite minerals in the soils. The presence of mottle colouration in the subsoils may be an indication of internal drainage problem due to presence of plinthic layers which restricted free movement of water within the soil body, during the rainy season. This causes the soil to be imperfectly to poorly drain during the rainy season.

The soils from PTA and NDY were deep to very deep effective soil depth of 75-105 cm and were relatively free from course fragments and were well-drained. Like soils described under the basement complex, the colour features of soils of PTA and NDY indicated a range of 2.5YR to 10YR which impacted them with red, dark yellowish brown, dark red, dark yellow brown and dark reddish brown.

Physical Properties

The physical properties of the soils of the four sites are presented in Table 1.

Table 1. Physical properties of soils from two different parent materials in Niger state, Nigeria

Site	Horizon	Soil Depth	Sand	Silt	Clay	Textural Class	Bulk density	Total porosity
		(cm)	(g kg-1)				(g cm-3)	(%)
GDM	Ap	0 – 30	774	160	66	LS	1.45	45
	Bt	30 – 46	614	140	246	SCL	1.50	43
	Btv	46 – 75	674	200	126	SL	1.67	37
NBK	Ap	0 - 33	721	180	99	SL	1.46	45
	Bt2	45 - 78	641	80	279	SCL	1.52	43
	Btvg	78 - 100	541	160	299	SCL	1.68	37
PTA	Ap	0 - 8	794	120	86	SL	1.38	43
	AB	8 - 50	774	140	86	SL	1.46	45
	Bt	50 - 100	614	220	166	SL	1.48	44
NDY	Ap	0 – 20	721	180	99	SL	1.32	50
	Bt1	20 – 75	761	120	119	SL	1.47	45
	Bt2	75 - 100	721	160	119	SL	1.48	44

*LS=loamy sand, SL= sandy loam, SCL= sandy clay loam

Source; Laboratory Experiment 2

The soils from GDM and NBK developed from basement complex, which have their textures to be loamy sand in surface horizons while sandy clay loam in sub-surface horizons respectively. The sand content follows the same pattern in all the soils of these sites; it decreased with soil depth. The silt content of these sites decreased and increased with soils depth.

The clay content of GDM and NBK increased with soil depth. The high sand fraction in surface horizon was also influenced by the parent material from which the soils are formed (Akpan-Idiok (2012); Peter and Umweni, 2021). The texture of PTA and NDY were sandy loam both in surface and sub-surface horizons. The sand content follows a particular pattern in all the soils, it decreased and increased with depth. Silt fraction from PTA and NDY were less in the topsoil's than in the sub soils, while clay content increased with depth. The relatively high sand content in the area was the reflection of the effect of parent material such as Nupe sandstones.

According to (Akamigbo and Asadu, 1983), the parent materials have been noted to influence the texture of the soils derived from them. The lower silt content in the soils may also be attributed to the effect of parent materials on the soils, as it has been reported by Akamigbo, (1984) that silt content is low in most soils of Guinea savanna of Nigeria.

Chemical properties

The chemical properties of the soils of study areas are presented in Table 2. Soil reaction was slightly acid to neutral with pH values of the surface soil as 6.3, 6.3, 6.3 and 6.5 for GDM, NBK, PTA and NDY respectively and were classified as slightly acid in all the sites. Organic carbon (OC) in GDM ranged from 1.46 to 2.33 g kg-1 and was high. OC in NBK ranged from 2.13 to 3.11 g kg-1 and was very high. OC in PTA ranged from 0.67 to 2.50 g kg-1, and was low to high. OC in NDY ranged from 6.72 to 9.01 g kg-1 and was very high. Organic carbon is an essential component of soil chemical parameter for tropical soils, contributing to aggregate stability, permeability, water holding capacity, nutrient retention, and other desirable soil properties. (Ravindra. et al.2017). Total N in the soils of all sites was very high (> 0.3 g.g-1). While available phosphorus was low, other sites had moderate to high values. The exchange capacity (CEC) values for all sites were generally low, except for PTA that was

Very low. According to (Chude, et al. 2011) rating, the concentration of exchangeable Ca_2^+ in NBK and NDY were very low and exhibited the pattern of increased and decreased with the profile depth. While it concentration in GDM and PTA was low and increased and decreased with soil depth. The concentration of exchangeable Mg was generally low in all the study sites and also exhibited increased and decreased pattern with soil depth. The concentration of exchangeable K in GDM, PTA, and NDY was very low, while in NBK was low both in surface and sub-surface horizons, and exhibited increased and decreased pattern with soil depth. The concentration of exchangeable Na in GDM and NBK was high in both surface and sub-surface horizons and exhibited increased and decreased with soil depth. While the concentration of Na in PTA and NDY was moderate, both in the surface and sub-surface horizons, and exhibited the pattern of increased and decreased with soil depth.

Table 2. Chemical properties of soils

Areas	Soil Depth	Ph	OC	N	P	Ca	Mg	K	Na	EA	CEC	BS	ESP
	(cm)	(H2O)	(g/kg-1)		(mg/kg-1)	(cmol/kg-1)			← →			(%)	(%)
Gidan Mangoro	0 – 30	6.3	1.46	0.46	13	2.88	0.96	0.07	0.83	0.04	8.40	56	9.88
	30 – 46	6.1	2.33	0.48	7	3.20	2.08	0.08	0.67	0.03	9.01	67	7.44
	46 – 75	6.2	1.46	0.36	10	2.40	1.12	0.07	0.58	0.04	7.11	59	8.16
	0 – 33	6.3	2.46	0.59	16	1.44	0.48	0.11	0.93	0.07	9.31	32	9.99
Nubwakoyi	33 – 45	6.0	3.11	0.53	17	1.28	1.44	0.11	0.54	0.09	9.03	37	5.98
	45 – 78	5.8	2.62	0.56	29	3.04	0.96	0.13	0.60	0.23	7.80	61	7.69
	78 – 100	6.1	2.13	0.84	23	3.20	1.76	0.15	0.56	0.30	8.20	69	6.83
Patita	0 – 8	6.3	2.50	0.42	10	2.24	0.96	0.06	0.62	0.05	5.02	77	12.35
	8 – 50	6.5	0.49	0.41	8	2.38	1.60	0.07	0.67	0.05	6.00	79	11.17
	50 – 100	6.3	0.67	0.48	8	2.08	1.44	0.05	0.54	0.05	9.58	43	5.64
Ndayako	0 – 20	6.5	6.72	0.36	9	1.60	0.96	0.05	0.50	0.11	10.40	30	4.81
	20 – 75	6.5	7.70	0.46	7	2.08	0.80	0.09	0.56	0.13	13.86	25	4.04
	75 – 100	6.6	9.01	0.42	3	1.92	0.96	0.05	0.53	0.15	11.88	29	4.46

Source: Laboratory Experiment 2023

7. Soil Taxonomic Classification of the Study Sites

The soils of Gidan Mangoro, Nubwakoyi, Patita and Ndayako presented in Table .3, were classified according to USDA Soil Taxonomy (Soil Survey Staff, 2022) and correlated with World Reference Base (WRB, working group 2022) soil resources.

Gidan Mangoro showed clay accumulation with 3.7 times clay content at Bt horizon relative to Ap, indicating presence of well-developed argillic horizon. Base saturation was > 35 %, thus, placing the soil under Alfisols at soil Order level. The soil was formed under ustic moisture regime, characteristic of the moist savannah vegetation zone in Niger State. On this basis, the soil was placed under Ustalfs at Suborder level and Plinthustalf at Great Group level due to presence of Plinthic materials within 150 cm depth (in this regard, 55 to 100 cm). At Subgroup level, it fitted into Typic Plinthustalf as all Plinthustalfs are provisionally place under USDA Soil Taxonomy. Gidan Mangoro have notable illuvial clay content within sub-surface horizons; with surface layers that have being altered by wet cultivation. This qualifies the soil as Haplic Plinthosols (Loamic) under WRB classification.

Nubwa Koyi had 1.2 times higher clay content at Bt1 than Ap confirming presence of a well-developed argillic horizon. Base saturation was low, hence placed under Ultisols at the USDA's Soil Taxonomy's Order level. The soil was formed under ustic moisture regime and therefore, further placed under Ustults at Suborder level.

Table. 3 Summary classification of the soils of the study sites

Sites	USDA				WRB
	Order	Suborder	Great Group	Subgroup	
Gidan Mangoro	Alfisol	Ustalf	Plinthustalf	Typic plinthustalf	Haplic Plinthosols (Loamic)
Nubwakoyi	Ultisol	Ustult	Kanhaplustult	Plinthic Kanhaplustult	Haplic Kandisols Plinthic
Patita	Inceptisol	Ustept	Haplustept	Oxic Haplustept	Eutric Cambisol (Oxyaquic)
Ndayako	Ultisol	Ustult	Kanhaplustult	Rhodic Kanhaplustult	Haplic Alisols (Loamic)

Source: Soil Taxonomic Classification 2023

This site had kandic horizon but lacked further diagnostic features that will require it placement perfectly into any class. As such it was classified as Kanhaplustults at Great Group level. The soil was classified as Plinthic Kanhaplustult at Subgroup level due to presence of plinthic horizon within 150 cm (in this case, starting from 78 cm depth). Under WRB classification, the soil of Nubwa Koyi was classified to be Haplic Kandisol Plinthic.

Patita showed no evidence of clay illuviation between AB and Ap horizon and therefore placed under Inceptisols at the USDA's Soil Taxonomy's Order level. The soil was formed under ustic moisture regime and therefore further placed under Ustepts at Suborder level and Haplustepts at Great Group level due to insufficient diagnostic criteria to qualify it to fit into other class at this taxon. It was further classified at Subgroup as Oxic Haplustept for having CEC < 24 cmol kg-1 clay at depth of 25 cm from mineral surface up to 100 cm depth. Under WRB classification, Patita had sub-layers that are not properly undergone significant pedogenic alteration and surface layer that had been altered by human activity (cultivation), this qualifies the soil Eutric Cambisol (Oxyaquic).

Ndayako showed 1.2 times higher clay content at Bt1 than Ap confirming presence of a well-developed argillic horizon. Base saturation was low and irregularly decreased with increasing soil depth. On this basis, the soil was placed under Ultisols at the USDA's Soil Taxonomy's Order level. The soil was formed under aquic moisture regime and therefore further placed under Ustults at Suborder level. Inadequate diagnostic features at Great Group level allowed its placement under Kanhaplustults. At Subgroup level, it was further classified as Rhodic Kanhaplustults for having colour of matrix with Hue of 2.5 and value of 3 (moist) and dry value not higher than 1 Under WRB classification, the soils of Ndayako were classified to be Haplic Alisols (Loamic).

Conclusion

The soils developed under basement complex rocks were shallow to deep soils while the soils from sedimentary rocks formations were deep to very deep. The soils of the study areas generally have favorable pH, high base status, but low to medium fertility. However, with adequate application of mineral fertilizers and organic inputs, the soils can be more productive.

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References

1. Akamigbo, F. O. R., & Asadu, C. L. A. (1983). Influence of parent materials on soils in southeastern Nigeria. *East African Agricultural and Forestry Journal, 48*, 81–91.
2. Akamigbo, F. O. R. (1984). The accuracy of field textures in humid tropical environments. *Soil Survey and Land Evaluation, 493*, 63–70.
3. Aki, E. E., Esu, I. E., & Akpan-Idiok, A. U. (2014). Pedological studies of soils developed on biotite–hornblende gneiss in Akamkpa Local Government Area, Cross River State, Nigeria. *International Journal of Agricultural Research, 9*(4), 187–199.
4. Akpan-Idiok, A. U. (2012). Physico-chemical properties, degradation rate and vulnerability potential of soils formed on coastal plain sands in southeastern Nigeria. *International Journal of Agricultural Research, 7*(7), 358–366.
5. Alabi, A. A. (2011). Geology and environmental impact assessment and benefits of granitic rocks of Minna area, northwestern Nigeria. *Ethiopian Journal of Environmental Studies and Management, 4*(4), x–x. https://doi.org/10.4314/ejesm.v4i4.5
6. Brady, N. C., & Weil, R. R. (1999). *The nature and properties of soils* (12th ed.). Prentice Hall.
7. Chude, V. O., Olayiwola, S. O., Osho, A., & Daudu, C. K. (2011). *Fertilizer use and management practices for crops in Nigeria* (4th ed.). Federal Fertilizer Department, Federal Ministry of Agriculture and Rural Development.
8. Esu, I. E. (2004). Soil characterization and mapping for food security and sustainable environment in Nigeria. In *Proceedings of the 29th Annual Conference of the Soil Science Society of Nigeria* (pp. 10–17).
9. Fasina, A. S., Omolayo, F. O., Ajayi, O. S., & Falodun, A. A. (2007). Influence of land use on soil properties in three mapping units in southwestern Nigeria: Implications for sustainable soil management. *Research Journal of Applied Sciences, 2*(8), 879–883.
10. Food and Agriculture Organization. (2006). *World reference base for soil resources: A framework for international classification, correlation and communication*. FAO.
11. Food and Agriculture Organization. (2018). *Status and challenges of soil management in Nigeria*. https://www.fao.org/
12. International Institute of Tropical Agriculture. (2015). *Selected methods for soil and plant analysis* (Manual Series No. 3). IITA.
13. Jagdish, P., Ray, S. K., Gajbhiye, K. S., & Singh, S. R. (2009). Soils of Selsura Research Farm in Wardha district, Maharashtra and their suitability for crops. *Agropedology, 19*, 84–91.

14. Lawal, B. A., Tsado, P. A., Eze, P. C., Idefoh, K. K., Zaki, A. A., & Kolawale, S. (2014). Effect of slope positions on selected properties of soils under a *Tectona grandis* plantation in Minna, Southern Guinea Savanna of Nigeria. *International Journal of Research in Agricultural and Forestry, 1*(2), 37–43.
15. Lekwa, M. U., Anene, B. O., & Lekwa, G. (2004). Chemical and morphological soil characteristics in a drainage toposequence in southeastern Nigeria. In Ojeniyi, S. O., Ano, A. O., Awasalam, D. O., & Chukwu, G. O. (Eds.), *Land degradation, agricultural productivity and rural poverty* (pp. 316–322). Soil Science Society of Nigeria.
16. Peter, K. D., & Umweni, A. S. (2021). Ilmu pertanian (agricultural science). *Jurnal Ilmu Pertanian, 6*(1), x–x. https://doi.org/10.22146/ipas.60307
17. Ravindra, H., Sehgal, M., Narasimhamurthy, H. B., Jayalakshmi, K., & Imrankhan. (2017). Rice root-knot nematode (*Meloidogyne graminicola*). *International Journal of Current Microbiology and Applied Science, 6*(8), 3143–3171.
18. Soil Survey Staff. (2022). *Keys to soil taxonomy*. United States Department of Agriculture.
19. Ukut, A. N., Akpan, U. S., & Udoh, B. T. (2014). Characterization and classification of soils in steep-sided hills and sharp-crested ridges of Akwa Ibom State, Nigeria. *Net Journal of Agricultural Science, 2*(2), 50–57.