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Research Article

Physical Properties and Classification of Soils of Research and Training Farm, Federal University of Agriculture, Zuru Kebbi State, Nigeria

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Abstract

Semi-detailed soil survey was carried out at the research and training farm of the Federal University of Agriculture Zuru. The objectives were to examine the morphological and physical properties of the soils. The soils were also classified according to USDA Soils Taxonomy System and correlated with the World Reference Base (WRB) for soil resources. A selected area of 16.4ha out of the total land area of the farm 99.9ha was used in the study. The survey was carried out at scale of 1:25,000. An interval of 250x250m was used in auguring. Surface and subsurface sample 0-15cm, 15-30cm depths. Three soil profile pits were dug, described and soils sampled from bottom up, to minimize contamination by falling debris. Each soil profile pit was described based on horizon thickness, depth, colour of matrix and mottles, texture, structure, consistency and horizon boundary characteristic. Three soil mapping units tagged FUZ1, FUZ2 and FUZ3 were identified. The soils were moderately drained and generally loamy sand to sand loam in texture. The physical properties of the soils indicated a relatively high bulk density, particle density and low porosity. According to USDA soil taxonomy classification, the soils of FUZ1 was classified as Aquic Dystrusterts, as Typic Haplustalfs and FUZ3 as Fluventic Dystroxerepts and correlated with Pellic Vertisols, Haplic Luvisols, Arenosols Stagnic (loamic) respectively in the World Reference Base (WRB) system.

Keywords: *Physical, Properties, Classification and Soil.*

1. INTRODUCTION

Soil is an unconsolidated material on the surface of the earth that has been subjected to and influenced by the genetic and environmental factors of parent material, climate, organisms, and topography, all acting over a period of time (SSSA, 2001). Agricultural viability depends upon a healthy soil. A healthy soil is obtained through knowledge of the soil and the application of appropriate management practices. Poor management practices can lead to soil degradation, which can reduce productivity. Soil is not a renewable resource. The loss of 1mm of topsoil can take 3000 years to be replaced (Baxter, 1968).

All soils contain mineral particles, organic matter, water and air. The combination of these determines the soil's properties (Brady and Weil, 2002). Information relating soil properties can be used to guide investment decision on a farm to maximize the benefit from investment (FAO, 2012). Three groups of soil properties influence plant growth, namely: physical, chemical and biological (CSIRO, 2006).

Soil classification is defined as the systematic arrangement of soils into groups or categories on the basis of their observed properties. observed properties are those that can be seen in the field or measured in the laboratory (AASHTO, 2012). Classification of soil deals with the systematic categorization of soils based on distinguishing characteristics as well as criteria that dictate choices in use (WRB, 2022).

Soil taxonomy is aimed at establishing hierarchies of classes that permit us to understand as fully as possible, the relationships among soils and between soils and the factors responsible for their character (Fasina and Adeyaju, 2006).

Geological changes in soil composition, texture, and properties may require hundreds to thousands of years. Over time, in the last thirty five years however, it has been realized that there are also changes in the properties of soils that can occur in weeks, months and years (Soil Survey Staff, 2015).

Classification systems based on observed properties are usually called natural classification or soil taxonomy. When soils are classified based on inferences from the observed properties, the classification system is called technical classification. For example, it could be inferred that crops grown on dark loam soils would have yields. Therefore, soils classified on the basis of potential yield are a technical system (FOA, 1998).

Taxonomy and the soil group system, published as the Word Reference Base for soil Resources developed by the food and Agriculture organization (FAO) of the United Nations. (FAO, 1998). Both of these systems are Morphogenetic, that they use structural properties as the basis of classification while also drawing on the five factors of soil formation in choosing which properties to emphasize. (ISSS-ISRC, 1998).

The central to both systems are the nation of diagnostic horizons, well-defined soil layers whose structure and origin may be correlated to soil forming process and can be used to distinguish among soil units at the highest level of classification. (Blume and Schad, 2015).

A taxonomy is an arrangement in a systematic manner; the USDA soil taxonomy has six levels of classification. They are from most general to specific: order, suborder, great group, subgroup, family and series (Soil Survey Staff, 1999).

WRB is a two-tier system of soil classification, with 32 major soil groups (the “Reference Base”) and over 120 uniquely defined qualifiers for specific soil characteristics (the “WRB Classification System”). Qualifiers are used to indicate the depth of occurrence or the degree of expression of certain soil features. (WRB, 2014).

2. MATERIALS AND METHODS

2.1 Location of the Study Area

The study was conducted at Research and Training Farm of the Federal University of Agriculture Zuru, Kebbi State located in the extreme south eastern part of the state on a hilly terrain, Zuru town lies on latitude $11^0$26’ – 18.4056”N and longitude $5^0$13’798”E. The climate of the area is typical of tropical climate, characterized by wet and dry seasons. The dry season is usually from November to May while rainy season from June to October. The area experiences annual rainfall of 1424mm per annum with average temperature of 20^0C to 27^0C (Yalmo, 1998).

2.2 Field Study

Semi-detailed soil survey was carried out at the research and training farm of the Federal University of Agriculture Zuru. A selected area of 16.4ha out of the total land area f the farm 99.9ha was used. The survey was carried out at scale of 1:25,000. An interval of 250x250m was used in auguring along the transects to identify soil types and their boundaries. Surface and subsurface sample 0-15cm, 15-30cm depths. Three soil profile pits were dug, described and soil sampled from bottom up to minimize contamination by falling debris.

Each soil profile pit was dug to standard size (200cm long, 100cm wide and maximum depth of 200cm or until an impenetrable layer or water table is encountered. Each pit was described based on morphological characteristics according to established standard procedure (Soil Survey Staff, 1999). The characteristics describes include soil depth, horizon thickness, colour of matrix and mottles, texture, structure, consistency, porosity, included materials, roots and horizon boundary. In addition, records of vegetation/land use, slope, depth to water table and internal drainage status was obtained for each profile. Three soil mapping units tagged FUZ1, FUZ2 AND FUZ3 were identified.

2.3 Soil Sampling

Following the descriptions, soil samples (disturbs and bulk) were collected from each genetic horizon for laboratory analyses.

2.4 Laboratory Methods

The samples were air-dried, carefully crushed using a wooden and pestles and then sieved through a 2mm mesh. The sieved samples were stored for physical analysis. Particle size was determined using the hydrometer method with sodium Hexameta Phosphate as the dispersing agent (Rhoades, 1982). Bulk density was determined with the use of core sampler method (Blake and Hartge, 1986). Particle density was determined using the formula:

PD $\frac{Weight\ of\ oven\ dry\ soil\ (g)}{Volume\ of\ soil\ (Cm^3}$

Total porosity was calculated mathematically using the formula:

$$F = 1 \left(\frac{bd}{pd}\right) \times 100$$

Where:

pd = Particle density
bd = bulk density
1 = constant value

Soils were classified using USDA soil Taxonomy Classification and were correlated with the World Reference Base (WRB) for soil Resources. The data was analyzed using descriptive statistics such as means and weighted averages.

3. RESULTS AND DISCUSSION

The morphological, physical properties and taxonomic classification of the soils were presented in tables 1,2,3 respectively.

3.1 Soil Morphological Characteristics

The morphological properties of the soils are presented in table 1

The morphological properties of the soils are presented in Table 1. The soils of all pedons are generally deep with depth of >140cm. The colour of the soil varied from very pale brown (10YR $^{2}/_{2}$) in the surface horizon changing to dark yellowish brown (10YR $^{3}/_{3}$) in the subsurface horizon. The texture of the soil varied from loamy sand to loam in the surface horizon changing to clay loam to silt loam in the subsurface horizon with strong angular blocky structure in the surface horizon changing to sub-angular blocky structure in the subsurface horizon. Similar result was found by (ESU, 2004). The consistence of the soils is sticky/plastic in both surface and subsurface of pedon 1, pedon 2 friable and 3 loose. The roots of the soils varied from many roots changing to few roots in the surface horizon and very few roots to no roots in the subsurface horizons. The horizon boundary of the pedon was smooth diffuse in the surface horizon and subsurface. The morphological characteristics of FUZ1 revealed features indicative of moderate profile development under seasonal wetness. The horizons display low organic matter content due to the exhibits of silty clay and illuviation of sand where finer particles accumulate due to percolation of water from the surface (Soil Survey Staff, 1999). The presence of grayish matrix colours and mottles indicates seasonal saturation and reduced conditions, a sign of imperfect drainage and gleying (Esu, 1999). Overall, the morphological features of FUZ1 shows vertical differentiation driven by clay translocation, periodic wetness and moderate soil development, such features are consistent with soils formed under alternating wet and dry tropical conditions. This is in line with finding of (ESU, 2004).

The morphological description of soil profile of FUZ2 revealed the presence of transitional horizons (ABg, ABI, AB2) which indicates gradual changes in soil formation and horizon development, possibly due to illuviation, clay migration or weak pedoturbation. This tallies with soil survey staff (1999) findings. The deeper horizons (AB1 to BC) indicates less organic matter, increased leaching or oxidized conditions (FAO, 2006). The dominance of sandy loam in upper layers indicates coarse material likely from parent materials or alluvial deposition. The transition to finer textures in lower horizons signifies clay illuviation which can affect water retention and root penetration. This is in line with (Landon, 1991) findings. The soils also increased compaction, clay content and low organic matter, potentially limiting root penetration and drainage (ESU, 2004).

The morphological characteristics of profile FUZ3 revealed moderate development of structure due to minimal clay content and weak aggregation. The light color of the soil showed typical of sandy soils with low organic matter content (Brady and Weil 2016). The friable consistency and many pores indicates good aeation and ease of tillage in the topsoil which is favourable for root growth and penetration but with limitations due to reduced porosity and nutrient status. This is agreed with the findings of Soil Survey Staff (1999). The lack of organic matter indicates poor biological activity and limited permeability. These conditions are common in deep subsoils of tropical Alfisol or Entisols with weak pedogenic development (FAO, 2006). The lack of mottling throughout the profile indicates good drainage conditions, confirming the soil is well-aerated and likely free from seasonal waterlogging, which is beneficial for most crops (Brady and Weil, 2016). The morphological properties indicates that FUZ3 is a young to moderately developed soil with weak horizon differentiation, good drainage, and low organic matter. Such soils typically require soil amendment (Eshett, 2003).

Table 1: Morphological Properties of the Soils

Horizon	Depth (cm)	Munsell color (moist)	Texture	Structure	Pores	Mottling	Consistency (moist)	Root	Horizon boundary
FUZ 1 (Aquic Dystrusterts)									
Ap	0-17	10RY 6/3	LS	ABK	MP	10YR 3/6	SP	MR	D
ABg1	17-47	10RY 3/2	SL	ABK	FWP	10YR 3/4	SP	FWR	SD
ABg2	47-82	10YR 3/3	CL	SABK	FWP	10YR 3/6	SP	VFWR	SD
BCg	82-141	10YR 3/4	Sic	ABK	NP	10YR 4/6	SP	NR	SD
FUZ 2 (Haplustalfs)									
Ap	0-20	10YR 5/3	SL	ABK	FWP	None	F	FWR	DS
ABg	20-56	10YR 6/4	SL	ABK	FWP	10YR5/3	F	VFWR	DS
AB1	56-124	10YR 8/6	SL	SABK	NP	None	F	NR	DS
AB2	124-178	10YR 7/4	Sic	ABK	NP	None	F	NR	DS
BC	178-200	10YR 8/4	CL	SABK	NP	None	F	NR	DS
FUZ 3 Fluventic (Dystroxerepts)									
Ap	0-31	10YR8/6	S	SABK	MP	None	L	FWR	DS
AB	31-83	10YR 6/8	SL	ABK	MP	None	L	FWR	DS
BC	83-200	10YR 8/4	SL	ABK	FWR	None	L	NR	DS

Texture: S = Sandy, LS = Loamy Sand, SL = Sandy Loam,
Structure: ABK = Angular blocky, SBK = Sub-Angular Blocky, SIL = Silt,
Colour: 10YR 6/3 = Very pale brown, 10YR 3/3 = Dark brown, 10YR 3/2 = Brown 10YR ¾ = Dark Yellowish brown, 10YR 5/3 = Brown, 10YR 5/4 = Light Yellowish Brown, 10YR 8/6 = Yellow, 10YR 7/4 = Very pale brown, 10YR 8/4 = Very Pale Brown, 10YR 6/8 = Brownish yellow,
Consistence: SP = Sticky/plastic, F = Friable, L = loose
Roots: MR = Many Roots, FWR = Few Roots, VFWR = Very Few Roots, NR = No Roots,
Boundary: D = Diffuse, DS = Diffuse Smooth,

3.2 Physical Properties of the Soils.

The physical properties of the soils are presented in table 2. The amount of sand in the soils varied in the surface horizon from 74.81% to 76.64% and increased to 79.84% to 80.10% in the subsurface of the horizon. High mean value of sand was reported and this indicated translocation of properties to deeper horizons. This finding is inline with the findings of (Brady and Weil, 2002). Similarly, the amount of silt content varied with depth which increased from surface to subsurface with mean value of 11.28% to 12.47%. The clay content of the soil has increased with depth which ranged from the mean value of 10.87% to 11.08% respectively. Yakubu (2006) reported similar findings.

The bulk density of the soil changed irregularly with depth from surface to subsurface with the mean value from 1.76gcm^3. The particle density of all the pedons appeared to have decreased slightly with depth with the mean value from 2.23gcm^3 to 2.06gcm^3 (Idoga *et al;* 2006), reported the similar findings. The porosity of the soils changed irregularly with depths in all pedons with the mean value from 9% to 21% respectively. According to Hillel (2004), high bulk density can limit root growth and reduce porosity, especially in compacted horizons.

Table 2: Physical Properties of the Soils

Horizon	**Depth (cm)**	**Particle size (%)**			**Bulk Density (BD) (gcm^3)**	**Particle Density (PD) (gcm^3)**	**Porosity %**
		Sand	**Silt**	**Clay**			
FUZ 1 ***(Aquic Dystrusterts)***							
AP	0-17	74.81	7.49	17.70	1.90	2.48	24
ABg1	17-47	76.64	10.08	12.96	1.82	2.31	22
ABg2	47-82	79.84	12.24	7.92	1.76	2.11	17
BCg	82-141	80.10	15.31	4.91	1.55	2.03	24
	Mean	**77.85**	**11.28**	**10.87**	**1.76**	**2.23**	**21**
FUZ 2 ***(Typic Haplustalfs)***							
AP	0-20	81.20	10.08	8.64	1.91	2.29	17
ABg	20-56	84.12	7.90	7.90	1.74	2.15	20
AB1	56-124	82.64	9.18	8.64	1.70	2.10	19
AB2	124-178	85.13	6.16	8.91	1.68	2.08	19
BC	178-200	86.56	2.88	10.04	1.65	2.07	21
	Mean	**83.93**	**7.24**	**8.83**	**1.74**	**2.15**	**19**
FUZ 3 ***(Fluventic Dystroxerepts)***							
AP	0-31	80.39	7.02	9.37	1.90	2.06	8
AB	31-83	83.70	12.68	10.08	1.92	2.04	6
BC	83-200	65.38	17.72	13.68	1.78	2.08	15
	Mean	**76.49**	**12.47**	**11.08**	**1.86**	**2.06**	**9**

3.3 Taxonomic Classification of the Soils

The soils were classified according to the USDA soil taxonomy system (USDA, 1999) and correlated with the FAO/UNESCO legend of the world Reference Based (WRB) system (WRB, 2022). The two systems are the most commonly used in Nigeria for soil classification. The three soils mapping units that were identified in the study area were designated as FUZ1, FUZ2 and FUZ3.

The soils of FUZ 1 were classified as Aquic Dystrusterts at subgroup level due to the aquic conditions for extended periods within 100cm of the soil surface (Soil Survey Staff, 2003). FUZ2 as Typic Haplustalfs at subgroup level because they do not have a natrix or kindic horizon (Soil Survey Staff, 2004). FUZ 3 as Fluventic Dystroxerepts due to the umbric or mollic epipedon and also for having irregular decrease in organic carbon content with depth (Soil Survey Staff, 2004). Correlated with World Reference Base (WRB) FUZ1 as Vertisols for accumulation of clay which tend to be poorly drained and alternating wet-dry condition shrink swell. FUZ2 as Luvisols for having an argillic horizon overlain by loamy sand and FUZ3 as Arenosols for having comprise texture class of sandy loam or loamy sand.

Table 3: Taxonomic Classification of the Soils

PEDON	Soil Series	USDA System	WRB System
1. FUZ 1	Foto-foto	*Aquic Dystrusterts*	*Pellic Vertisols (clayic)*
2. FUZ2	Gonar Nenu	*Typic Haplustalfs*	*Haplic Luvisols (loamic)*
3. FUZ 3	Gonar Dangoje	*Fluventic Dystroxerepts*	*Arenosols Stagnic (loamic)*

Figure 1: Plates of Identified Profiles

Plate 1: FUZ 1: (Aquic Dystrusterts*)*

Plate 2: FUZ2: (Typic Haplustalfs)

Plate 3 FUZ3: (Fluventic Dystroxerepts)

4. CONCLUSION

It is revealed that soils in the study area were deep to moderately deep, moderately drained and generally loamy sand to sand loam in texture. The physical properties of the soils indicated a relatively high bulk density, particle density and low porosity. According to USDA soil taxonomy system FUZ1 was identified as Aquic Dystrusterts, FUZ2 Typic Haplustalfs and FUZ3 as Fluventic Dystroxerepts and correlated with World Reference Base (WRB) FUZ1 as Pellic Vertisols, FUZ2 Haplic Luvisols while FUZ3 Arenosols Stagnic.

5. RECOMMENDATIONS

1. The use of heavy machineries and over grazing should be minimized
2. Complete removal or burning crops residues in the farm should be discouraged

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