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Variation in Morphological Properties and Particle Size Distribution of Alfisols, Inceptisols and Entisols in the Gubi Soil Series, Bauchi, Nigeria

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Abstract: The morphology and particle size distribution of three different soils Alfisols, Inceptisols and Entisols in the Gubi Soil Series, Bauchi were studied. The investigation revealed that the soils were generally deep and sandy in texture although the Entisol contains more silt than the sand fraction. Both the Afisols and Inceptisols had transitional horizons between the A and B horizons and also contain kandic (k) horizons. The topsoil colours in the Alfisols and Inceptisols were dominantly dark brown while the subsoils were yellowish to yellowish brown. The Entisols had dark yellowish brown to dark gray colour at the surface and light gray to olive brown in the subsoil. Soil structure was weak coarse subangular blocky for the Inceptisols and Alfisos (except for one profile in the Alfisol which together with the Entisols was structureless. Soil consistence was moist and friable or moist and very friable across soil types. There was evidence of organism (roots) in all the profile with plenty iron concretions and calcium nodules. A proper management of these soils will require additions of organic matter and fertilization with inorganic fertilizers for optimum crop production.

Key words: Morphological properties, particle size, Alfisols, Inceptisols, Entisols, Gubi soil series

INTRODUCTION

Soil is commonly described as a three-phase system, composed of solid, liquid and gaseous phases. In most soils, the solid phase make up the vast majority of the soil mass and over half its volume. Esu (1999) stated that soil participles are the discrete units which comprise solid phase of the soi land that these particles have diverse composition and structure and generally differ from one another in both size and shape. The solid phase is the subject of this study. The properties of a soil are closely related to the factors of soil formation and the processes of soil change. According to Briggs (1977), the character of the solid particles and the way in which they are packed together determine the physical properties of the soil. Thus, the physical conditions of the soil involve two related aspects-the nature of the individual solid particles and the aggregates which these form. Soil physical properties are said to influence how soils function in an ecosystem and how they can best be managed. Soil scientists use the colour, tenure and other physical and morphological properties of soil horizons in classifying soil profiles and in making filed determinations about soil suitability for agricultural and environmental projects. According to Brady and Weil (1999) soil texture and structure help determine the nutrient supplying ability of soil solids as well as the ability of the soil to hold and conduct the water and air necessary for plant root activity. These properties also determine how soils behave when used for building construction and foundations, or when manipulated by tillage.

Soil morphological properties such as horizons development, soil colour, soil structure, consistence, pores and the presence of roots and animals are brought about partly by soil architecture and partly by chemical and biological processes that take place within the soil. Most soil colours are derived from the colours of iron oxides and organic matter that coat the surfaces of soil particles. Organic coatings tend to darken and mask the colours derived from iron oxides. Other minerals that sometimes give soils distinctive colours are manganese oxide, glauconite and carbonates. Soil structure defines the pattern of pores and peds which greatly influences water movement, heat transfer, aeration and porosity in soils. Soil consistence is important for tillage and traffic considerations as it deals with the strength and nature of the forces between particles.

The Gubi soil series was classified by Voncir (2002) into Alfisols, Inceptisols and Entisols. This study attempts to compare the inherent properties of these various soil types within the same series to document any variation between and within them.

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MATERIALS AND METHODS

Site information: The study area is located at Gubi, about 12 km North West of Bauchi Town. The geology of the area is mainly undifferentiated basement complex with granite as the predominant parent material. Gentle plains running from the base of the inselbergs to the major watercourses characterize the site. The climate makes for two seasons-dry and wet seasons lasting from October to March and April to September, respectively. The mean monthly temperatures vary between 22.2°C in December and 29.7°C in April/May. The area lies within the northern guinea savanna ecological zone of Nigeria with stony and moderately deep soils and an ustic soil moisture regime and isohyperthermis temperature regime. The vegetation consists of grassland interspersed with trees and shrubs including *Combretum* sp., *Parkia clappertomana* and *Butyrospermum parkii*. L and use includes the cultivation of millet, sorghum, cowpea and grazing.

Soil survey: Six profile pits, two each representing the Alfisols, Inceptisols and Entisols were dug and the morphological properties of each genetic soil horizon in each pit was described following standard procedures as described by Soil Survey Manual (Soil Survey Staff, 1999). Soil samples were then collected and subjectel to laboratory analyses.

Laboratory analysis

Particle size distribution: This was determined using the hydrometer method as described by Bonyouncos (1951).

Statistical analysis: Data collected were subjected to statistical analysis in a nested design using the Minitab soft ware F-test. The Least Significant Difference (LSD) as described by Steel and Torrie (1981) was used to separate means that were statistically significant.

RESULT AND DISCUSSION

Morphological properties

Alfisols: The morphological properties of the Alfisols represented by profiles 01T4 and 01T3 are shown in Table 1.

The depth of the profiles (118 and 130 cm) and the degree of horizon differentiation is indicative of a long process of pedogenesis although changes apparently are still occurring as typified by the transitional horizon (BK1-A) in both profiles. The horizons hare appreciable accumulation of calcum minerals as well as concretions and nodules cemented mostly by oxides of iron. They have in addition to the argillic horizons, kandic horizon that starts approximately at the center of the pit. Fanning and Fanning (1989) have stated that the processes involved in the genesis of Alfisols include eluviation and illuviation of silicate clays- in the better drained soils and associated iron oxides. They also stated that the parent materials and C horizons of Alfisols commonly were/are calcareous. It is therefore most probable that there was high amount of calcium as well as iron in the parent materials. The presence of a kandic horizon in both profiles further confirms that they are Alfisols.

The top soils were sandy loam in texture with colours that are dark brown (7.5YR 3/8) to dark reddish brown (5YR 3/2) while the sub soils were yellow (5/R 4/9; 10YR 6/6; 10YR 6/4) and red (2.5YR 4/6) sandy loam to sandy clay loam. Although the upper horizons of these soils have high chroma values, the lower horizons have lower chroma values and yellower hues which are typical of Alfisols. The darker surface soils may be due to the presence of organic matter. Soil structure was structureless (massive) in profile 01T4 with common few fine roots and weak coarse sub-angular blocky in profile 01T3 with medium and common fine and coarse roots. The massive structure in profile 01T4 may be due to farming activities while profile 01T3 was relatively undisturbed.

Inceptisols: These are represented by profiles 02T1/03T1 and 00T2/01T2. As shown in Table 2 profile 02T1/03T1 is deep (115 cm) while profile 00T2/01T2 is moderately deep (60 cm) with both profiles having transitional horizons. Throughout profile 02T1/03T1, except for the surface soil iron concretions and calcium nodules occur. The presence of few and mostly transitional diagnostic horizons indicate that the soil have undergone some more pedogenic processes than an Entisol would otherwise be but not enough such that it excludes it from the more developed soils. The genesis of this soils seem to be through the processes of mineral and organic matter transformations coupled with eluviation, but with little illuviation, or with two little accumulation of illuvial substances to constitute spodic or argillic horizons as explained by Fanning and Fanning (1989). According to them, youthfulness at least in terms of degree of profile development is considered the common genetic characterizes of Inceptisols. The topsoils are dark brown (10YR 3/3; 7.5YR 3/2) loam and sandy loam while the lower horizons have dark brown to yellowish. Brown (7.5YR 4/4; 10YR 5/6) sandy loam and sandy clay loam soils.

The near similarity in colour especially the dark colour in both the surface and subsurface soil may be a confirmation of the theory of transformation and eluviation of mineral substances and organic matter with little illuviation such that materials are almost distributed evenly. The soils have weak subangular blocky structures and contain common fine and medium roots.

Table 1: Morphological properties of Alfisols at Gubi

Horizon	Depth (cm)	Colour (moist)	Texture	Structure	Const. (moist)	Boundary	Misc. obs.
Profile 01T4							
A	0-13	7.5YR 3/8	SL	0 m	mfr	CS	fine, med. andcoarse roots
Bk1-A	13-35	5YR 4/8	SCL	0 m	mfr	gs	fine, med. and coarse roots
Btk2	35-57	2.5YR 4/6	SCL	0 m	mfr	gs	comm.coarse roots Ca
Btck3	57-92	5YR 5/8	SC	0 m	mfr	gs	few med. roots Ca nodules
Btck4	92-130	10YR 6/6	SCL	0 m	mfr	-	comm. Fe, few fine roots and Ca nodules
Profile 01T3							
AP	0-14	5YR3/2	SL	1csbk	mvfr	CS	Comm. fine roots
Bck1-A	14-31	5YR4/4	SL	1csbk	mvfr	gs	Comm. and med. roots, comm. Fe Conc.and Ca nodules
Bck2	31-63	10YR6/4	SCL	1csbk	mfr	gs	Few fine roots, Comm. Soft Fe. Conc. Ca nodules
Bck3	63-118	10YR/73	GR-SL	1csbk	mfr	-	Few fine roots: Many soft Fe Conc. Ca nodules

Table 2: Morphological properties of Inceptisols at Gubi

Horizon	Depth (cm)	Colour (moist)	Texture	Structure	Const. (moist)	Boundary	Misc. obs.
Profile 02T1/03T1							
AP	0-26	7.5YR 3/2	LS	ksbl	mfr	CS	Fe coarse and Comm.. med. Roots
CL1-A	26-57	10YR 5/6	GR-LS	ksble	mrfr	gs	Comm. Fine and med. Roots ca. nodules
Cck2-B	57-115	5YR 5/6	GR-SCL	0 m	mfr	-	Many soft Fe conc. Few v. fine roots Ca-nodules
Profile 00T2/01T2							
A	0-24	10YR 3/3	L	lcsbk	mfr	gs	Common fine and medium roots.
AB	24-34	7.5YR 4/4	SCL	lesbk	mfr	gs	Common fine and med. roots
BC	34-60	7.5 YR 4/4	SL	ksbl	mfr	-	Few fine and med. roots

Table 3:Morphological properties of Entisols at Gubi

Horizon	Depth (cm)	Colour (moist)	Texture	Structure	Const. (moist)	Boundary	Misc. obs.
Profile 00T1							
AP	0-28	10YR 4/4	SL	0 m	mfr	CS	Few med. and comm Fine roots
Cc1	28-58	10YR 5/6	V.GR-LS	Osg	mrfr	gs	Fe and mn. Conc. Few fine roots
Cc2	58-90	10YR 6/6	V.GR-LS	Osg	mrfr	gs	Few fine roots; Many hard Fe and Mn. Conc.
Cc3	90-126	2.5Y7/2	V.GR-LS	Osg	mrfr	-	Few medium roots
Profile 02T2/02T3							
A	0-15	2.5Y3/2	Sic	0 m	mfr	gs	Comm. V. fine roots
Ct1	15-28	2.513/3	CL	0 m	mfr	cs	Few coarse and comm. Fine roots; few Fe and Mn. Conc.
Cc2	28-62	2.5Y4/4	CL	0 m	mfr	gs	Ca nodules
Cc3	62-82	2.5Y4/4	SC	0 m	mfr	a1w	Ca. conc.
Cc4	82-121	2.5Y4/4	SiCL	0 m	mrfr	CS	Few V. fine roots; Comm.. Fe and Mn. Conc.
Cc5	134	2.5Y4/4	SiCL	0 m	mfr	CS	Few V. fine roots; Comm.. Fe and Mn. Conc.

Entisols: Table 3 shows the two profiles, 00T1 and 02T2/02T3 that represent the Entisols. The soils are deep (126 and 134 cm) and range in colour from dark yellowish brown (10YR 4/4) to dark grayish brown (2.5 Y 3/3) at the surface and light gray (2.5Y 7/2); dark olive brown (2.5Y 3/3) and olive brown 2.5Y 4/4 in the lower horizons. The topsoils are sandy loam to silt clay while the lower horizons have textures that are clay loam to silt clay loam to very gravelly loamy sands. Profile 00T1 is much of saprolite. They are structureless and single grain in profile 00T1 and massive in profile 02T2/02T3. There are few medium and common fine roots with many hard iron concretions. The soil colours are a reflection of the environment; most of these Entisols occur on floodplains or have impeded drainage. The constant near saturation and continuous removal of materials by water cannot allow for the formation of good soil structure. There was plenty calcium nodules in the profile.

Particle size distribution

Alfisols: The particle size distribution for the Alfisols is shown in Table 4. The sand fraction was high within the profiles but the content decreased with depth while the clay content increased with depth. The silt content was somehow irregularly distributed in profile 01T4 but decreased with depth in profile 01T3. There was however, no significant difference in particle size within the profile.

Inceptisols: The Inceptisols also had high sand contents in their profiles with less clay (Table 5) compared to the Alfisols. The sand content in profile 00T2/01T2 was found to increase with depth. The silt content of this profile was also high especially at the surface. The high amount of silt could be indicative that the soil is still undergoing pedogenesis even though at a slow rate considering the amount of sand in the profile. Again there was no significant difference in the particle size distribution within the profile.

Entisols: The particle size distribution for Entisols is shown in Table 6. The Butoisols especially pedon 02T2/02T3 had the highest content of silt within this soil series with low sand content compared to the other soil profiles in the series. This profile is on the floodplain and

Table 4: Particle size distribution Alfisols at Gubi

Horizon	Depth (cm)	Sand (%)	Silt (%)	Clay (%)	Textural class
Profile 01T4					
A	0-13	74	11	15	SL
Bk1-A	13-35	64	21	15	SL
Btk2	35-57	65	12	23	SCL
Btk3	57-92	51	19	30	SCL
Btk4	92-130	48	23	29	SCL
	Mean	64.59	15.15	20.45	
Profile 01T3					
AP	0-14	62	33	15	SL
Bk1-A	14-31	55	35	10	SL
Btk2	31-63	56	11	33	SCL
Btk3	63-118	55	15	30	SCL
	Mean	58.65	25.02	21.33	
Mean		61.62	20.08	20.89	

Table 5: Particle size distribution of Inceptisols at Gubi

Horizon	Depth (cm)	Sand (%)	Silt (%)	Clay (%)	Textural class
Profile 02T1/03T1					
AP	0-26	80	10	10	SL
Ck1-A	26-55	78	11	11	SL
Cck2-	57-115	70	15	15	SL
	Mean	76.39	11.80	11.80	
Profile 00T2/01T2					
A	0-24	44	35	21	L
AB	24-34	61	27	12	SL
CB	34-64	80	4	16	SL
	Mean	64.50	18.32	17.18	
Mean		70.45	15.06	14.49	

Table 6: Particle size distribution of Entisols at gubi

Horizon	Depth (cm)	Sand (%)	Silt (%)	Clay (%)	Textural class
Profile 00T1					
AP	0-28	59	25	16	SL
Cc1	28-58	74	11	15	SL
Cc2	58-90	74	8	18	SL
Cc3	90-126	73	15	12	SL
	Mean	66.32	18.25	15.44	SL
Profile 02T2/02T3					
A	0-15	25	53	22	SiL
Cc1	15-28	32	40	25	L
Cc2	28-62	47	36	17	L
Cc3	62-82	17	51	32	SiCL
Cc4	82-121	33	51	16	SiL
Cc5	121-134	20	59	21	SiL
	Mean	29.89	49.70	21.25	
Mean		47.60	33.97	18.35	
Overall: LSD (p = 0.05) soil type		NS	NS	NS	
LSD (p = 0.05) depth		NS	NS	NS	

this probably explains the high amount of silt material which might have been deposited by alluvial processes. There was also no significant (p = 0.05) difference in particle size distribution within the profiles of this soil type. The occurrence of this soil on the flood plain may also explain why the pedogenenetic process is slow making the soil and Entisol.

Overall there was no significant difference in the particle size distribution of the three soil types under consideration. This may be because these soil have been developed from the same sedentary parent material (basement complex rocks).

CONCLUSIONS AND RECOMMENDATION

The result of this study indicates that the soil are predominantly sandy in texture with similar morphological characteristics except where modified by other and environmental factors. The soils therefore require careful management especially the addition of organic matter to improve the structure and the addition of inorganic fertilizer for economic crop production.

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