



Morphological Characterization of Soils Along a Toposequence in Yamaltu-Deba Local Government Area, Gombe State, Nigeria



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ABSTRACT

This study examined soil morphological characteristics along a toposequence in Yamaltu-Deba Local Government Area of Gombe State. Ten soil pedons were excavated and described at upper, middle, and lower slope positions across the study locations of Kwadon, Dadinkowa, Kanawa, Wajari, Zambuk, Baure, Kwali, Boltongo, Deba, and Jangerigeri, following standard soil survey procedures. Morphological properties assessed included profile depth, horizonation, soil colour, texture, structure, consistence, and root distribution. The soils were generally deep to very deep, with profile depths ranging from 150 to 200 cm, indicating suitability for crops with deep rooting systems. Soil colours ranged from dark brown to yellowish brown, while mottles observed in several subsoil horizons indicated seasonal water table fluctuations. Surface horizons were predominantly loamy sand and sandy loam, with increased clay content in subsurface horizons due to eluviation–illuviation processes along the toposequence. Soil structure in surface horizons was mainly weak to moderate sub-angular blocky, while consistence ranged from friable to very firm under moist and wet conditions, reflecting differences in moisture retention and plasticity across landscape positions. Distinct horizon development was evident in most pedons, highlighting the influence of topography on pedogenesis. Based on morphological characteristics, the soils were classified mainly as Alfisols, with Inceptisols and Entisols occurring at specific slope positions. The observed morphological and classification variations provide valuable information for soil classification, land evaluation, and sustainable management in the Northern Guinea Savanna Zone of Nigeria. practices such as organic matter addition, reduced tillage, and erosion control measures are recommended to improve soil structure and sustain productivity.

Keywords:

Soil morphology,
Toposequence,
Pedons,
Soil classification,
Yamaltu-Deba,
Gombe

INTRODUCTION

The basis of pedological research is soil morphological characteristics, which offer vital information for comprehending soil origin, categorization, and land-use potential. According to Brady and Weil (2017), these characteristics such as soil color, texture, structure, consistency, horizon differentiation, depth, boundary characteristics, and the existence of diagnostic features are direct manifestations of pedogenic processes that are influenced by a variety of factors, including climate, parent material, relief, organisms, and time. In soil surveys and land assessments, field-based morphological description is still essential, especially in tropical savanna areas where soils show significant spatial diversity.

In Nigeria, the location of the landscape and the intrinsic properties of the soil have a significant impact on agricultural output. Shallow effective depth, poor structural development, erosion susceptibility, and drainage constraints limit many soils; these factors are typically best understood by in-depth profile morphological descriptions (Esu, 2010). Thus, the foundation of soil categorization systems like the USDA Soil Taxonomy and the World Reference Base for Soil Resources is in situ soil profile characterisation (Soil Survey Staff, 2014; International Union of Soil Science Working Group World Reference Base, 2015). Gombe State is located in the Northern Guinea Savanna ecological zone,

where soil-forming processes including eluviation–illuviation, iron oxidation, and organic matter dynamics are strongly influenced by alternating wet and dry seasons. The soils are exposed to ongoing agriculture, grazing, and seasonal bush burning. They are mostly formed from sedimentary and foundation complex parent materials. These elements lead to significant changes in soil profile development along landscape positions when paired with topographical variables (Yakubu and Ojanuga, 2013). Yamaltu-Deba Local Government Area (LGA) is a major agricultural zone in Gombe State, supporting rain-fed cultivation of cereals, legumes, and tuber crops. Farming activities occur across different landscape positions ranging from uplands to lower slope and valley bottom areas. Nevertheless, there is a dearth of precise and location-specific data on the physical features of the soil in these landscape areas. In Gombe State, the majority of earlier research has concentrated on assessing soil fertility and physicochemical characteristics, with little attention paid to thorough profile-level morphological descriptions across toposequences (Hassan *et al.*, 2018; Ojanuga *et al.*, 2015). Understanding soil morphological diversity along landscape positions in Yamaltu-Deba LGA is crucial given the impact of topography on soil formation and land-use suitability. Accurate soil categorization, the understanding of soil genesis, and the development of sustainable land management techniques all depend on this information. Thus, in Yamaltu-Deba Local Government Area, Gombe State, this study was carried out to describe the soil morphological characteristics of specific soil profile pits situated on various landscape positions (upper slope, middle slope, and lower slope). The particular goals were to provide baseline data for soil categorization and sustainable agricultural land use in Nigeria's Northern Guinea Savanna zone, describe soil layers and their morphological characteristics in situ, and assess variations in soil morphology along the landscape.

MATERIALS AND METHODS

Location and Extent of the Study Area

The study was conducted in Yamaltu-Deba Local Government Area (LGA), one of the eleven LGAs in Gombe State, located in northeastern Nigeria. The area lies between latitudes 10°10' and 10°35' N and longitudes 11°10' and 11°45' E, covering an estimated land area of 1,981 km². Yamaltu-Deba LGA is bounded by Adamawa State to the south and east, Akko and Kwami LGAs to the west, and Dukku LGA to the north. The terrain consists of low hills, dissected plateaus, isolated inselbergs, and gently undulating plains, with elevations ranging from 400 to 700 m above sea level and a general southward slope toward the Gongola River basin. Drainage is dominated by the Gongola River and its tributaries, which serve as important seasonal and perennial water sources for domestic and agricultural activities. The climate is

tropical continental (West African type), characterized by two distinct seasons: a dry season (November–March) and a wet season (April–October). Mean annual rainfall ranges from 750–850 mm in the northern part of the LGA to 1,400–1,600 mm in the southern part, with peak rainfall occurring in July and August. The hottest months are March to May, during which maximum temperatures may reach 43°C. Mean annual temperatures range from 27–28°C in the Sudan Savanna zone to 18–27°C in the Guinea Savanna zone. Relative humidity is generally higher during the rainy season and declines markedly during the dry season due to the influence of the northeasterly Harmattan winds (Upper Benue River Basin Development Authority, 2025).

For this study, ten soil profile pits (pedons) were excavated and described along a toposequence at selected locations within the LGA, representing upper, middle, and lower slope positions

FIELD RECONNAISSANCE AND SITE SELECTION

To determine key landscape locations and representative sites within the study area, a reconnaissance survey was carried out. Three typical sites were chosen along a toposequence based on differences in topography, slope, and land use. To record the impact of topography on soil morphological development, profile pits were placed on the upper, middle, and lower slopes.

SOIL PROFILE EXCAVATION AND DESCRIPTION

At each chosen location, a 1.5 m × 1.5 m soil profile pit was dug down to a depth of 150–200 cm, or until the groundwater table or an impenetrable layer was reached. After being cleaned, the exposed soil profiles were ready for a thorough morphological description. In accordance with FAO rules and standard procedures given by the Soil Survey Staff (2014), soil horizons were identified and documented in situ. Horizon designation, horizon depth and thickness, soil color (dry and moist), soil texture by feel method, soil structure (type, size, and grade), soil consistency (dry, moist, and wet), nature of horizon boundaries (distinctness and topography), root distribution and abundance, and the presence of concretions, mottles, pores, cutans, or other diagnostic features were among the morphological characteristics noted.

SOIL SAMPLING

For laboratory analysis, samples of disturbed soil were taken from each identified horizon. Before analysis, samples were gently crushed, air-dried, and run through a 2-mm sieve. In order to determine certain physical parameters, undisturbed core samples were also gathered where needed.

SOIL CLASSIFICATION

The soils were categorized using the USDA Soil Taxonomy (Soil Survey Staff, 2014) and correlated with the World Reference Base for Soil Resources (IUSS Working Group WRB, 2015) based on the observable morphological features and laboratory data.

DATA ANALYSIS

Descriptive statistics were used to summarize soil morphological characteristics across profile pits and landscape positions. Variations in morphological properties were interpreted in relation to topography, drainage condition, and land-use history.

RESULTS AND DISCUSSION

Soil depth

Soils of the study area recorded depths ranging from 150 to 200 cm (Table 1). The deepest pedons were located at Kwadon, Dadinkowa, Zambuk, Baure and Kwali, having depths of 200 cm each, closely followed by the pedon at Kanawa, with a depth of 180 cm. However, pedons at Boltongo, Wajari and Jangerigeri, had depths that varied from 150 to 175 cm (Table 1). The Soils of the study area were generally found deep to very deep (Esu, 1991). The major limiting factor to soil depth include the occurrence of high-water table or an impermeable layer in situ. The depth of all the soil profiles studied, will permit effective crop roots proliferation and elongation.

Soil colour

The kind, amount and distribution of organic matter, various mineral constituents, mainly iron compounds and or stagnant water table cause soils to appear in different colours (Alem *et al.*, 2015). However, drainage condition, geology and physiographic position have the major influence on soil colour (Abu and Malgwi, 2012). Soils from majority of the studied pedons had a dark brown (7.5YR) dry colour, all through their depths, with slightly variable values, while moist colour was dominantly yellowish brown (10YR4) at the surface tending towards dark brown (2.5YR3/4) and dark brown (5YR) at the subsoil at variable (Table 1). The brown colour, on surface horizons of pedons AMRP1 and P2 (amaranth), MNGP1 and P2 (mango), RCEP1 and P2 (rice) land use types, might be ascribed to effect of organic matter content while dark yellowish-brown colour of the sub surface horizons might be attributed to iron compound in various state of oxidation and decreased organic matter content. One of the most distinct and diagnostic morphological characteristics that indicate the seasonal fluctuation of water table in soils is the presence of mottles. Mottling was observed to be totally absent in pedons at Dadinkowa, Kanawa, Kwali, Boltongo and Jangerigeri. However, mottling was observed in the subsoils of pedons at Kwadon, Wajari, Zambuk, Baure

and Deba, varying from common medium and distinct (cmd), mmd and fine, few and faint (fff) (Table 1). These features are indications of soil wetness brought about by oxidation-reduction cycles due to ground water fluctuation (Oso *et al.*, 2012).

Soil texture

Soil texture is an important soil physical property which affects water holding capacity, nutrient retention capacity, organic matter content and soil aeration (Kefas *et al.*, 2016). Soils of the surface horizons of pedons at Kwadon, Dadinkowa and Kanawa were observed to be Loamy sand in texture, while the subsurface soil texture of the pedons were found to be variable and range from Loamy sand to Sandy loam and clay, while surface horizons of pedons at Wajari, Zambuk, Kwali and Boltongo were observed to be sandy loamy in texture, while the subsurface soil texture of the pedons were found to be variable and range from sandy loam, loam and clay (Table 1) However, pedon at Baure was observed to be clay in texture throughout the profile. Nevertheless, the texture of these soils reflected the parent rocks from which they are formed (Ahukaemere *et al.*, 2012; Ahukaemere *et al.*, 2016).

Soil structure

The results from this study indicated that strong fine Sub angular blocky (3fsbk) and moderate medium sub angular blocky (2msbk) structures, dominate surface soil structures, while weak (1msbk) to moderate (2msbk) medium sub angular blocky structures, dominate subsurface soil structures across all the pedons (Table 1). However, at Baure the massive structure type dominated, largely due to its high clay content

Soil consistence

Soil consistence comprises the attributes of soil minerals that are expressed by the degree and kind of cohesion and adhesion or by the degree of resistance to deformation or rupture. Surface soils of pedons at Wajari, Zambuk, Kwali and Boltongo, had a wet, moist and dry consistencies that are predominantly slightly sticky (ss), friable (fri) and soft (s), respectively. Even though, pedons at kwadon, Dadinkowa and Kanawa had similar wet and moist consistencies with the above locations, but recorded slightly hard (sh) consistencies under dry condition (Table 1). Equally, at the subsurface levels, across the pedons, predominantly slightly sticky (ss), friable (fri) and soft (s) consistencies for wet, moist and dry conditions, respectively, were observed, with some few exception, such as very sticky (vs), very plastic (vp), firm (fi) and hard (h) to very hard (vh) consistencies, were recorded in pedons at Baure and Zambuk (Table 1). However, the increased sticky consistence (wet) with increase in soil depth observed in some pedons (Table 1) is a sign of clay lessivation (Brady and Weil, 2017).

Horizonation

Horizonation is ascribed to addition, losses, translocation and transformation of organic matter and colour development, very evident for soils under vegetational condition. Generally, horizonation is promoted in the soils by mineralization from the humification of organic matter in the A horizon. Horizon designations followed USDA Soil Taxonomy guidelines. The Ab horizons were identified based on buried surface characteristics, including darker colour and higher organic matter relative to overlying materials, indicating depositional processes. Bt horizons were recognized by increased clay content and evidence of illuviation compared to overlying horizons. The presence of Cg horizons was justified by gleyed colours and mottling, reflecting prolonged saturation and poor drainage conditions in lower slope positions. All the pedons observed in this study generally showed a clear horizonation between the Ap and lower B horizons (Table 1). The boundaries were predominantly described as clear and smooth (CS), for the surface

horizons, while at the subsurface, occurrence of diffuse boundary was observed at Kwadon, Kanawa, Zambuk, Kwali, Boltongo and Deba. The more distinct horizonation in pedons across the different locations may be due to sedimentation pattern in the area which had resulted in discontinuities within the profile. Discontinuities were recognized in the field by colour, texture and consistence which gave clear and abrupt boundaries to subjacent layer (Malgwi, 2001).

Plant roots are commonly abundant in the surface horizons (Ap) horizons of most of the pedons and are usually referred to as the zone of active root activities. The surface soils of all the studied pedons across the different locations had roots which ranged from common medium to few fine roots, while the subsoils had few fine roots (Table 1). It was also observed that the content of roots decreased as soil depth increases.

Table 1: Soil Morphological Properties in the Study Area

Pedon	HD	Depth (cm)	Mottle	Soil Colour		Texture	Structure	Consistency			Boundary	Inclusions
				(moist)	(Dry)			Wet	Moist	Dry		
Pedon1 KWADON	Ap	0-48	N	7.5YR 7/3	10YR5/4	LS	2fsbk	Ss	Fri	sh	CS	Common medium roots
753682.9224	Ab	48-92	N	7.5YR 5/4	10YR3/4	SL	2msbk	Ss	Fri	s	DF	Few medium roots and pores
1128860.72 Elv= 357m	C	92-215	Cmd	7.5YR 3/3	10YR2/3	SL	2fsbk	Ss	Fri	s		Few medium roots
Pedon2 DADINKOWA	Ap	0-51	N	7.5YR 7/6	10YR6/6	LS	3fsbk	Ss	Fri	sh	CS	Many medium roots
770265.3283	Bt	51-95	N	7.5YR 5/3	10YR3/3	C	2msbk	Vs	fi	vh	CS	Common medium roots
1141309.672 Elv=220m	Bw	95-140	N	7.5YR 5/4	10YR4/6	LS	2msbk	Ss	Fri	sh	CS	Few medium roots
	C	140-205	N	7.5YR 4/2	10YR2/3	C	1csbk	Vs	fi	vh		Few fine roots
Pedon3 KANAWA	Ap	0-28	N	7.5YR 7/6	10YR6/6	LS	3fsbk	Ss	Fri	sh	CS	Many medium roots and pores
753682.922	Ab	28-49	N	7.5YR 5/3	10YR3/3	LS	2msbk	Ss	Fri	sh	DF	Few medium roots
112886.72 Elv=384	Bw	49-77	N	7.5YR 5/4	10YR4/6	SL	3fsbk	Ss	Fri	s	CS	Few medium roots
	C	77-180	N	7.5YR 4/2	10YR2/3	C	1csbk	Vs	fi	vh		Few fine roots and pores
Pedon4 WAJARI	Ap	0-26	N	7.5YR 5/3	10YR6/3	SL	3fsbk	Ss	Fri	s	CW	Common medium roots
785542	Bw	26-89	N	7.5YR 8/2	10YR10/2	L	2msbk	Sp	fi	sh	CS	Many coarse roots
1169722 Elv=320	Cg	89-160	Mmp	5YR 6/4	7.5YR7/4	C	1csbk	Vs	fi	vh		Few fine roots
												Few fine roots
Pedon5 ZAMBUK	Ap	0-26	N	7.5YR 4/3	10YR6/4	SL	3fsbk	Ss	Fri	s	CW	Common medium roots
758712	Ab	26-64	N	7.5YR 5/3	10YR6/3	SL	2msbk	Ss	Fri	s	DF	Common fine roots
1142151 Elv=296	Bt	64-120	Cmd	7.5YR 7/2	2.5YR8/2	C	1msbk	Vs	fi	vh	CW	Few fine roots
	Cg	120-200	Mmp	5YR 7/2	7.5YR7/6	C	1cfsbk	vsv p	vfi	vh		No root
Pedon6 BAURE	Ap	0-59	N	7.5YR 2/2	10YR3/2	C	2msbk	Vs	Fi	vh	CS	Common medium roots
777997	Bt	59-110	N	7.5YR 6/3	10YR5/6	C	2msbk	vsv p	Vfi	vh	CS	Few common roots
1126178 Elv=343	Bt2	110-165	N	10YR 7/3	2.5YR5/6	C	1msbk	vsv p	Vfi	vh	CS	Few fine roots
	Cg	165-200	Cmd	10YR 7/3	2.5YR7/6	C	1csbk	vsv p	Vfi	vh		No root

Table 1 Cont'd

Pedon	HD	Depth (cm)	Mottle	Soil Colour		Texture	Structure	Consistency			Boundary	Inclusions
				(moist)	(Dry)			Wet	Moist	Dr y		
Pedon 7 KWALI	Ap	0-33	N	7.5YR 5/8	5YR4/8	SL	2msbk	Ss	Fri	S	CS	Common medium roots and pores
764151	Ab	33-120	N	7.5YR 4/3	5YR5/6	SL	2msbk	Ss	Fri	S	DF	Few medium roots and pores
1140985	B	120-165	N	7.5YR 6/4	2.5Y5/6	SL	1msbk	Ss	Fri	S	CS	Few fine roots
Elv=266	C	165.-201	N	7.5YR 5/6	10YR7/4	CL	1csbk	Vsvp	vfi	Vh		No root
Pedon 8 BOLTONGO	Ap	0-26	N	7.5YR 4/4	10YR5/4	SL	3fsbk	Ss	Fri	S	CS	Common medium roots and pores
753688	Ab	26-75	N	7.5YR 5/6	10YR6/6	SL	2msbk	Ss	Fri	S	DF	Common medium pores
1127720	C	75-150	N	10YR 8/1	2.5Y8/2	L	2msbk	Sp	fi	Sh		Few fin pores
Elv=398												
Pedon9 DEBA	Ap	0-66		7.5YR 2/4	7.5YR 2/4	L	2msbk	Sp	fi	Sh	CS	Common fine roots
758817	Ab	66-150	Fff	10YR 6/8	10YR5/6	L	2msbk	Sp	fi	Sh	DF	No roots
1132070	B	150-185	N	10YR 6/8	10YR5/6	SL	3fsbk	Ss	Fri	S	CS	No roots
Elv=335	C	185-210	N	10YR 6/3	2.5Y7/3	L	2msbk	Sp	fi	Sh		Many medium pores
Pedon10 JANGERIGERI	Ap	0-33	N	5YR4/8	7.5YR6/4	SC	2msbk	S	fi	Sh	CS	Common fine roots
757123	Bw	33-89	N	5YR4/6	7.5YR7/4	SL	3fsbk	Ss	Fri	S	CS	Few fine roots
1133892	C	89-175	N	2.5Y5/8	5YR6/8	L	2msbk	Sp	Fi	Sh		No root
Elv=381												

KEY: HD = Horizon Designation, Texture: LS = Loamy Sand, SL = Sandy Loam, SC= Sandy Clay, L= loam, C = Clay .Structure: 3fsbk=weak fine sub angular blocky, 2fsbk = moderate fine sub angular blocky, 2msbk = moderate medium sub angular blocky, 1csbk = strong coarse sub angular blocky, 1msbk = strong medium sub angular blocky. Consistence: Moist; fi=firm, vfi=very firm, fr = friable, vfr = very friable l = loose. Wet; s = sticky, vs = very sticky, ns = non sticky, np = non plastic, vp= very plastic. Dry; s = soft, h=hard, vh= very hard, l = loose. Boundary: CS = clear smooth, CW = clear wavy, DF= diffused

CONCLUSION

The study revealed considerable variation in soil morphological properties along the toposequence in Yamaltu-Deba Local Government Area, Gombe State. The soils were generally deep to very deep, with profile depths ranging from 150 to 200 cm, suggesting favourable conditions for root development and crop production. Different drainage conditions, parent materials, and landscape positions were mirrored in variations in soil color, texture, structure, and consistency among the pedons. While underlying strata showed higher clay content, suggesting the presence of clay translocation processes, top horizons were primarily loamy sand to sandy loam in texture. The majority of the soil structures were weak to moderate sub-angular blocky, indicating the weak structural development common to savanna soils that are continuously farmed. Particularly at lower landscape positions, the existence of mottles in several subsurface horizons suggested sporadic variations in the water table. The majority of pedons exhibit clear horizon differentiation, which indicates active pedogenic processes impacted by sedimentation patterns and organic matter accumulation. Overall, Yamaltu-Deba LGA's soils show morphological traits typical of Northern Guinea Savanna soils, with terrain

mostly controlling variances. The data produced by this study provide a helpful starting point for land assessment, soil categorization, and the development of suitable soil management techniques in the region. practices such as organic matter addition, reduced tillage, and erosion control measures are recommended to improve soil structure and sustain productivity. Overall, the findings provide a reliable basis for soil classification, land evaluation, and the development of site-specific, sustainable soil management strategies in the Northern Guinea Savanna zone of Nigeria

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