



Research Article

Morphological Variations of Soils in Alluvial Floodplain of Sokoto Northwest Nigeria

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ABSTRACT

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This study investigated the morphological characteristics of soils formed under alluvial floodplain conditions in the Rabah District of Sokoto state, covering an area of 170ha. Six mapping units were identified, and twelve pedons were excavated and analyzed from different depths within each unit. RBH5, covering 54ha, was the dominant unit, while Tsallaken Diga, with 7ha, had the least coverage. Soil morphology varied with depth (1.2m – 2m), showing gleying in all units except RBH3. Gleyed horizons exhibited dark grey colors with mottles in various shades. Matrix soil colors ranged from 10YR, 7.5YR to 5YR, textures from clay loam to loam, and soil structures varied from fine angular blocky to very fine angular blocky due to seasonal flooding. Lithological discontinuity was observed in RBH4, RBH5, and RBH6, while illuvial processes led to the accumulation of subsurface clay horizons (Bt) in most pedons. Cracking due to shrinkage and swelling of high-activity clay was noted in RBH1 and RBH3. The study concludes that repeated flooding events cause variations in alluvial soils, affecting horizon distribution and morphological properties, ultimately impacting soil texture and structure. Effective management is crucial for maintaining agricultural productivity and sustainability in flood-prone areas

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INTRODUCTION

Floodplains were actually productive environments due to the frequency of inundation and duration of flooding that brings in nutrient-rich-sediments from surrounding watersheds to the floodplain (Mitsch and Gosselink, 2000). They have low gradients and were liable to seasonal flooding at the peak of the rainy seasons (Ojanuga *et al.* 2003). They vary widely in morphological characteristics both within and between valleys owing to differences in morphogenesis, location, hydrological regimes, lithologic origins and climatic conditions. They were therefore, known to vary considerably in their fertility status from very fertile to those poor in fertility (Akamigbo 2001). Floodplain soil ranged from undeveloped to strongly developed horizons (Akamigbo 2001). One important characteristic of floodplains is their dynamic nature, with soil properties depending on topographic location, parent material, and water content (Buji *et al.* 2021).

Soil morphological properties were properties of the soil that can be seen and/or felt which were related to soil forming factors, the climate, parent material, topography, drainage, vegetation and age of the landscape (Dent and Young, 1981). Soil morphology is an in-situ examination of soil profiles under field conditions. Soil morphology is also field observable attributes of the soil within the various soil horizons and the description of the kind and arrangement of the horizons (Buol *et al.* 2003). The observable attributes ordinarily described in the field consist of horizon designation, soil color, soil texture, soil structure and soil consistency, other features such as mottling, distribution of roots and pores, evidence of translocated materials such as carbonates, iron, manganese, carbon etc. were all part (Buol *et al.* 2003). Studying soil morphological

properties provides insights in understanding soil formation processes. Thus, soil morphological properties were related to soil physical and chemical properties. They were cheap and quick to determine, as a result they were used in soil survey to reduce cost (Dent and Young, 1981).

Therefore, morphological characterization is a major building block for understanding the soil, they were the first milestone that provide information about soil before classification and evaluation (Buji *et al.*, 2021). Also, Akamigbo (2001) noted that soil characterization and classification usually mean criteria based on soil morphology in addition to characteristics developed during soil formation. Therefore, there is need to study the morphology of the soils formed under floodplain for understanding and subsequent classification purpose. Hence, this study was conducted to characterized some morphological variations of soils formed under alluvial soils of Sokoto state Nigeria.

MATERIALS AND METHODS

The Study Area

The study was carried out in Rabah District, Rabah Local Government area of Sokoto State. The area occupies a representative area of about 170ha, which was used for morphological study. It is situated about 50km east of Sokoto Metropolis, between latitudes $13^{\circ} 5' 45''$ to $13^{\circ} 8' 45''$ N and longitudes $5^{\circ} 28.5' 45''$ to $5^{\circ} 33.5' 45''$ E. Sokoto State is located in the North Western part of Nigeria on latitude $13^{\circ} 0' 21.1428''$ N and longitude $5^{\circ} 14' 51.1872''$ E at an elevation of 308m above sea level within the Sudan Savannah vegetation zone (Latlong.net, 2020). The study area is bounded in the North by the main Rabah road along General Hospital and Local Government Secretariat which crosses to Rabah Community; in the South by the River Sokoto (main source of water for the

floodplain). The Eastern boundary is Maikujera road while to the West is the Tomatoes Garden. The floodplain is saucer in shape, from the convergence of three slopes, which were generally gentle, convex and concave.

Field Study

Soil survey

A field visit (reconnoitre) survey of 450ha was carried out on the area to conduct a preliminary examination of the landscape and slope position to understand the features. Afterward, a detailed soil survey of selected 170ha at a scale of 1: 10,000 was conducted using the standard method as described by Hildebrand (1966). A series of parallel traverse lines (100m X 100m) on a fixed rigid grid pattern were set out and observation were made at every 100m intervals along the baseline to identify the kind of soils in the area using Dutch auger. Data on geographic coordinates and altitude were recorded at each observation point. At each interval the morphological properties examined were colour (using the Munsell Soil Colour Chart), texture and consistency (using sense of feel method), effective soil depth, surface stoniness, mottling, structure, cementation, concretion, rock fragments, presence of iron-manganese, and slope were determined in accordance with Soil Survey Manual (1993). Coordinates of examination point were obtained with the use of a Garmin E-trex 10 hand held GPS device. Based on the soil variation observed during Dutch auger examinations, soils were separated/delineated. Areas with similar kinds of soil were put under one mapping unit while areas with dissimilar kinds of soil were further examined for accurate location of the boundary between them. For each of the soils identified, two standard profile pits were sunk to a depth of 2.0m. Each profile was demarcated into different horizons. The

depths of each horizon were measured and each was described in accordance with the pattern of Guidelines for Soil Description (FAO, 2006).

RESULTS AND DISCUSSION

Brief overview of floodplains and study site

Floodplains are low-lying areas of land where floodwater periodically spreads when a river or stream overtops its banks. The soils usually consist of levees, sands, silts and clay deposited during floods. Levees are the heaviest materials (usually pebble-size) and they are deposited first; silts and sands are finer materials (Goudie, 2004). Floodplains are useful for farming, especially for the cultivation of rice and fish. The peat lands, which are a type of wetlands, are also good for production of fuels. They are also used for sports and recreational purpose, for amusements, boating festivals, fishing and sailing events (Nwankwoala, 2012). Floodplains in Nigeria are now becoming the “food basket” because they serve as the main source for growing crops for man and food supply to livestock all year round. Floodplain serve as the backbone of arable crop production in the semi-arid and arid savannah agro-ecological zones of sub-Saharan Africa where rainfall is limiting for agricultural productivity. Floodplain act as key resources for cultivators and pastoralists, providing a source of arable land or grazing during droughts or dry season. Apart from sustaining rural livelihoods and increasing food security, wetland patches allow the opportunity for diversification of crop production and the provision of a wide range of direct and indirect benefits (Ogban and Babalola, 2009). Cultivation of crops in the floodplain area is one of the major components of urban agriculture, it is wide spread in Nigeria and it is attractive to urban crop production because of its high nutrient status and moisture

availability during the dry season (Giroh *et al.*, 2010).

The study site it's a floodplain comprising of toe slope and back swamps levee with an altitude ranging from 248 to 263m above sea level. The parent material is alluvial or a mixture of alluvial colluvial materials. The soils were deep, imperfectly to poorly drained with mostly gleyed properties. It is located on a sloping plain of 0-4 % slope, its stretches from the banks of river Sokoto to the outer edges of the valley. The different soil classes occupy same physiographic unit (geographical area characterized by specific landforms, topography and other physical features) on the landscape.

The floodplain of Rabah is occupied by intense agricultural production such as irrigated rice cultivation, vegetables, cowpea, orchard, and semi-permanent cultivation after the floods (Yakubu, 2006). Olaleye *et al.* (2001) identified morphological properties such as soil colour, soil texture, soil structure

and soil consistency as an important soil property in floodplains. Therefore, information is needed on these properties of the soil to ascertain its productivity.

Extent and Distribution of Mapping Units

The Rabah (RBH) floodplain soil series and their extent of coverage of the selected 170ha site were presented in (Table 1). The entire mapped area (about 170ha) was resolved into six (6) mapping units (soil series) and were named as Tsallaken Diga (RBH1), Hauki 1 (RBH2), Dan Bolo (RBH3), Mahijin Riji (RBH4), Rabah (RBH5) and Hauki 2 (RBH6). The distribution of the six (6) soil series identified were shown in (Fig. 1). Tsallaken Diga (RBH1) had the least area coverage of 7 ha (4%), followed by Dan Bolo (RBH3) with 17ha (10%), Mahijin Riji (RBH4) had 25ha (15%), Hauki 1 (RBH2) had 32ha (18%), Hauki 2 (RBH6) with 35ha (21%) and finally Rabah (RBH5) with 54ha (32%) having the largest area coverage.

Table 1: Extent and Distribution of Rabah Floodplain Mapping Units

S/No.	Soil Series	Hectares (Ha)	Area (%)
1.	Tsallaken Diga (RBH1)	7	4
2.	Hauki 1 (RBH2)	32	18
3.	Dan Bolo (RBH3)	17	10
4.	Mahijin Riji (RBH4)	25	15
5.	Rabah (RBH5)	54	32
6.	Hauki 2 (RBH6)	35	21
	Total	170	100

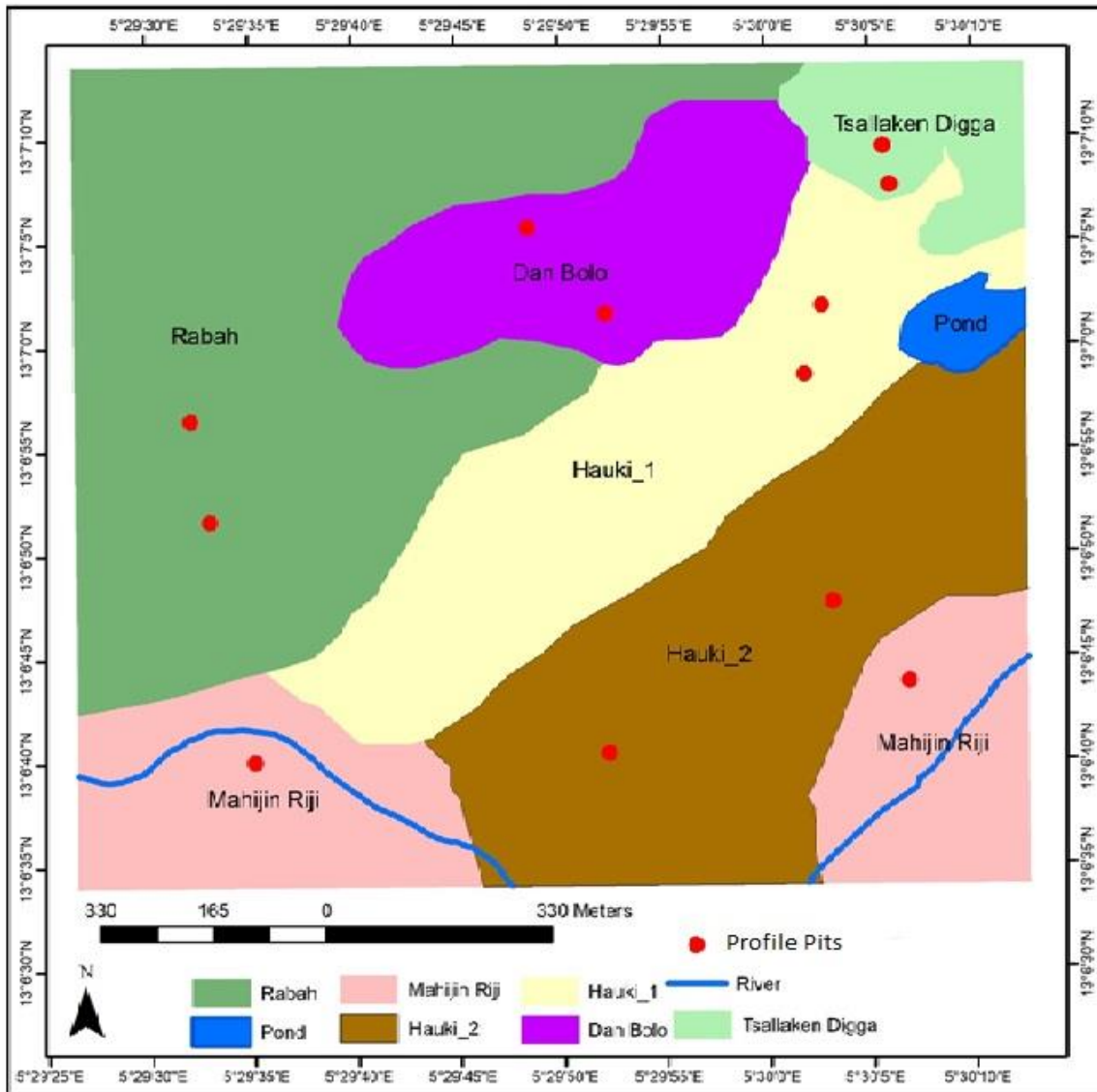


Figure 1: Map Showing Distribution of Rabah Floodplain Mapping Units as Well as Location of Profile Pits

Morphological Properties of the Soils of Rabah Floodplain

Morphological properties of the soils of Tsallaken Diga soil series (RBH1)

Tsallaken Diga (RBH1) had the least area coverage of 7ha (4 %), having clay loam as texture. The soil is located at the upper right hand corner of the map. Summary of the soil morphological properties of RBH1 were given in Table 2. Two profile pits were dug namely P1 and P2. The soils of RBH1 P1 and

P2 were deep and were imperfectly drained. Morphologically, the soils were composed of a series of horizons. The horizon designations of RBH1 P1 were A-BAg-Btg-Btg1-Btg2-Btg3 while those of P2 were A-ABg-Btg-Btg1-Btg2. The two pedons were similar in their designation, however P1 was more developed and has vivid Horization than P2 (Plate 1 and 2). Both pedons have Btg in their subsurface layers. The minor intra-variation in their horizon designation could

be due to effect of topography and the nature of the floodplain where different materials were deposited from upland. The colour of the soils at the surface ranges from dull yellowish brown (10YR5/3 dry) to dull yellow orange (10YR 6/4 wet) for P1. At the subsurface of P1, a Btg3 horizon of grayish yellow brown (10YR 6/2 dry) was found while same layer under wet condition is dull yellowish brown (10YR 5/4) with abundance of many to common mottles of orange (7.5YR 6/8 and 6/6) with similar occurrence in P2. The greyish yellow brown and common mottles at the subsurface is due to the nature of the soils which were wetland, and it agrees with the finding of Babalola *et al.* (2011) that major morphological features such as grey or low chroma (<3) colour and mottles were characteristic of floodplain soils, and it is an indication of soil wetness brought about by oxidation-reduction cycle due to ground water fluctuation. The dull yellowish brown to dull yellow orange colours indicates the presence of ferric-iron oxide as reported by Brady and Weil (2008). The textural classes of P1 and P2 were clay loam both in the surface and subsurface horizon respectively. The structure of the soils ranges from fine angular blocky (surface) to very fine angular blocky at the subsurface, according to FAO (1986) the characteristics nature of such soil structures is indication that the soils were still young. Soil consistency of the pedons were taken both in wet and dry conditions. The wet consistency ranges from sticky at the surface

and slightly sticky at the subsurface, while at the dry conditions the soil consistency ranges from slightly hard at the surface of P1 and hard at P2 to very hard to extremely hard at the subsurface of both pedons. The variation of hardness is because of the amount of soil moisture and clay presence in the soil down the profile (Baver and Winterkoru, 1935). The horizon form “topography and distinctiveness” of P1 and P2 were presented in Table 2. The thickness and topography of the soil ranges from wavy clear boundary at surface changing to wavy gradual boundary at mid-subsurface and finally wavy diffuse boundary at extreme subsurface. The soils RBH1 P1 and P2 have a medium very deep cracking surface of about 1-2cm wide and around 38cm deep “Plate 3”. The cracks were characterized by opening during dry season and close during wet season periodically. According to FAO (2006) guidelines for soil classification, such soil is classified as Vertisols. The cracking could be attributed to the shrinkage and swelling of the high activity clay in the area. Major land use is arable cropping with rice as a major crop. Some morphological features which may constitute constraint on the potentials of RBH1 for agricultural use were high content of clay right from the surface horizon downward, which implies dominance of high micro-pore spaces and consequently may limits water percolation and movement within the profile, hence creating waterlogged situation that is unfavourable to rooting zones.

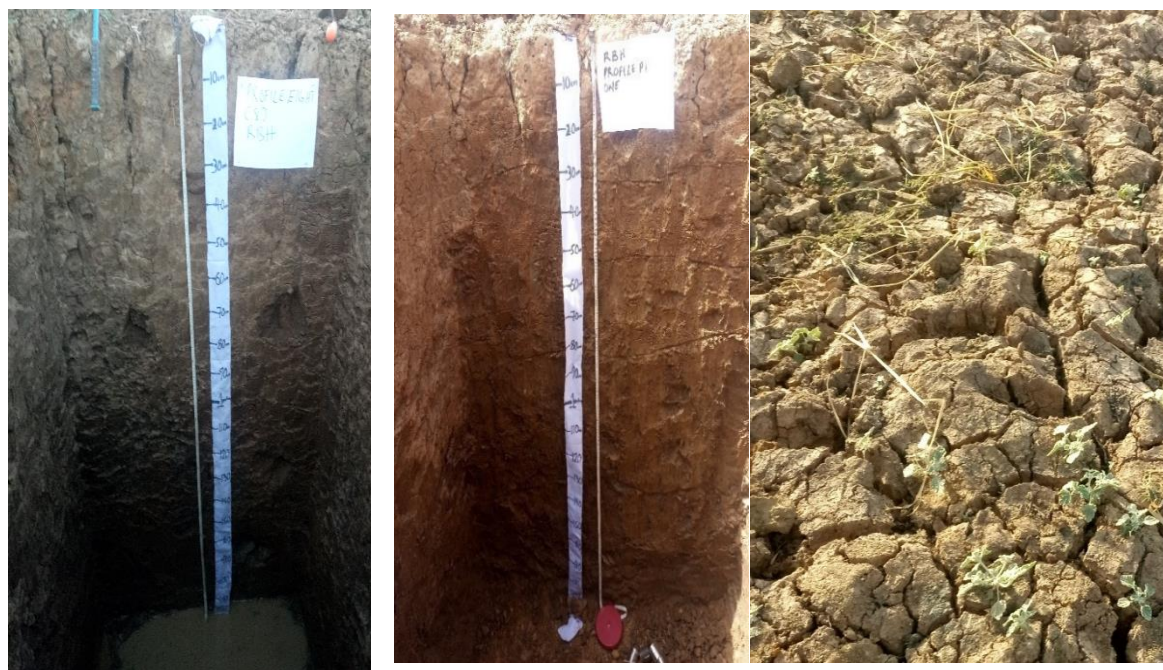


Plate 1 and 2 Profile pit of Tsallaken Diga (RBH1) P1 and (RBH2) P2

Plate 3: Surface of Tsallaken Diga series, showing Gilgae and cracking surface due to swelling and shrinking properties of clay

Table 2: Summary of Morphological properties of all soil series

Pedon (P)	Depth	Horizon Designation	Colour			Textural Class	Structure	Consistence		Boundary Form
			Dry	Moist	Mottles			WET	DRY	
P1	0-17	A	10YR5/3	10YR6/4	7.5YR6/8	CL	FBK	ST	SHA	WC
	17-36	Btg1	10YR6/2	10YR5/4	7.5YR6/8	CL	FBK	ST	SHA	WC
	36-57	Btg2	10YR6/4	10YR4/6	7.5YR6/8	CL	FBK	ST	HA	WG
	57-85	Btg3	10YR5/3	10YR3/4	7.5YR6/8	CL	FBK	VST	VHA	WG
	85-137	Btg4	10YR6/2	10YR5/4	7.5YR6/8	CL	VFBK	VST	VHA	WD
	137-200	Btg5	10YR5/3	10YR5/1	7.5YR6/8	CL	VFBK	VST	EHA	
Tsallaken Diga (RBH1)										
P2	0-23	A	10YR7/3	10YR6/2	7.5YR6/6	CL	FSBK	ST	HA	WD
	23-66	ABg	10YR4/4	10YR5/3	7.5YR6/6	CL	FSBK	SST	SHA	WD
	66-93	Btg1	10YR5/3	10YR4/3	7.5YR6/6	CL	FBK	ST	HA	IG
	93-152	Btg2	10YR6/2	10YR5/4	7.5YR6/6	CL	FBK	VST	VHA	ID
	152-200	Btg3	10YR6/4	10YR5/1	2.5YR5/8	CL	FBK	VST	VHA	
P3	0-5	A	10YR6/4	10YR5/6	7.5YR6/8	SL	VFBK	FR	SHA	WA
	O5 - 13	Ag1	10YR6/4	10YR5/6	7.5YR6/8	SL	VFBK	FR	SHA	WC
	13-35	Ag2	10YR7/8	10YR5/6	7.5YR6/8	SL	VFSG	LS	LO	WC
	35-66	B1	10YR7/6	10YR6/6	-	SL	VFSG	LO	LO	WD
	66-81	Bg	10YR6/4	10YR6/8	7.5YR6/8	SL	VFSBK	FR	SO	SC
	81-112	Btg	10YR5/3	10YR4/2	7.5YR6/8	L	FBK	FI	SHA	SD
	112-129	BCg	10YR6/2	10YR3/2	7.5YR6/8	SL	VFSBK	LO	LO	SC
	129-200	C	10YR7/6	10YR5/3	-	SL	VFSBK	LO	SHA	-
	Hauki 1 (RBH2)									
P4	0-12	Ap	10YR6/4	10YR7/2	-	SL	MSBK	FR	HA	SG
	Dec-25	ABg	10YR6/4	10YR7/4	7.5YR6/8	SL	MSBK	FR	HA	SG
	25-44	Bg1	10YR6/4	10YR6/6	7.5YR6/8	SL	FBK	FR	HA	SD
	44-67	Bg2	10YR6/3	10YR5/2	7.5YR6/8	SL	FSBK	FR	HA	WD
	67-87	BCg1	10YR5/3	10YR4/3	7.5YR6/8	SL	FSG	LO	LO	WG
	87-141	BCg2	10YR4/4	7.5YR5/4	7.5YR6/8	SL	FSG	FR	SHA	WD
	141-163	C1	10YR6/8	10YR4/6	-	SL	FSG	FR	SHA	WD
	163-200	C2	10YR7/8	10YR5/6	-	SL	FSG	FR	LO	-
P5	0-36	Ap	10YR4/6	10YR6/4	-	SL	wABK	NST	LO	ID
	36-135	AB	7.5YR5/6	10YR6/8	-	SL	wABK	SST	SO	ID
	135-200	B	7.5YR4/6	5YR5/8	-	SL	wABK	SST	SO	

Dan Bolo (RBH3)										
P6	0-57	Ap	10YR5/4	10YR3/4	-	LS	FC	NST	LO	WD
	57-169	AB	5YR5/6	7.5YR5/6	-	SL	FC	SST	SO	ID
	169-200	B	7.5YR5/6	7.5YR4/6	-	SL	FC	SST	SO	
P7	0-29	Ap	10YR5/3	10YR6/4	5YR5/8	C	FBK	VFI	HA	WD
	29-80	Btg	10YR5/3	10YR4/3	5YR5/8	SiCL	VFBK	FR	SO	ID
	80-125	B1	10YR8/4	10YR7/4	-	SC	FSG	FR	SO	IA
	125-138	B2	10YR6/6	10YR5/6	-	LS	VFBK	FI	HA	SA
	138-200	2Btg	10YR6/3	10YR3/6	5YR5/8	C	FBK	EFI	EHA	-
Mahijin Riji (RBH4)										
P8	0-18	Ap	10YR5/1	10YR4/1	7.5YR5/6	C	FBK	VFI	HA	SD
	18-61	ABg	10YR6/3	10YR4/3	7.5YR5/6	SiCL	VFBK	FR	SO	ID
	61-106	B1	10YR6/3	10YR6/6	-	SL	FSG	FR	SO	SD
	106-122	B2	10YR7/3	10YR4/3	7.5YR5/6	LS	VFBK	FI	HA	WD
	122-200	Btg	10YR6/2	10YR4/2	7.5YR6/8	C	FBK	EFI	EHA	-
P9	0-14	Ap	10YR6/4	10YR6/4	7.5YR7/8	C	MBK	VST	HA	SG
	14-55	ABg	10YR6/2	10YR4/3	7.5YR7/8	C	MSBK	SST	HA	ID
	55-91	Bg1	10YR6/4	10YR5/4	7.5YR7/8	L	FSG	SST	SHA	WG
	91-120	Btg1	10YR5/3	10YR4/3	7.5YR7/8	C	FBK	EST	EHA	WD
	120-163	Btg2	10YR7/3	10YR5/2	7.5YR7/8	L	FBK	SST	HA	SD
	163-186	2Bg	5YR4/4	10YR6/2	5YR4/4	CL	VFBK	ST	HA	SD
	186-200	2Btg	5YR4/6	10YR5/2	5YR4/6	C	FBK	ST	HA	-
Rabah (RBH5)										
P10	0-25	Ap	10YR7/2	10YR5/2	5YR7/8	C	CSBK	VST	HA	SG
	25-45	Bg1	10YR6/1	10YR3/3	5YR7/8	C	MSBK	SST	HA	ID
	45-93	Bg2	10YR7/3	10YR6/3	5YR7/8	SiL	MSBK	SST	SHA	WG
	93-120	Bg3	10YR6/4	10YR6/3	7.5YR6/6	SiL	MSBK	EST	EHA	WD
	120-144	Bg4	10YR7/4	10YR4/3	7.5YR6/8	L	MSBK	SST	HA	SD
	144-181	Btg1	10YR7/2	10YR4/1	5YR5/6	C	MBK	ST	HA	SD

	181-200	Btg2	10YR5/3	10YR5/2	5YR5/6	C	MBK	ST	HA	-
P11	0-14	Ap	10YR6/3	10YR7/3	10YR7/6	L	FBK	FR	LO	SG
	14-30	ABg	10YR7/3	10YR8/2	10YR7/6	LS	FSBK	FR	LO	WG
	30-66	Btg	10YR6/4	10YR5/4	10YR7/6	C	FBK	FI	SL H	WD
	66-94	2B1	10YR5/4	10YR5/8	-	SC	CSG	FR	LO	SG
	94-143	2B2	10YR4/3	10YR6/6	-	LS	F SG	LO	LO	ID
	143-164	2Bg	10YR5/3	10YR5/3	10YR7/6	SiL	FBK	FI	HA	WG
	164-200	2Btg	10YR6/2	10YR4/1	10YR7/6	C	FBK	FI	HA	-
Hauki 2 (RBH6)										
P12	0-29	Ap	10YR6/4	10YR4/6	7.5YR6/8	L	FBK	FR	SO	SD
	29-43	ABg	10YR7/3	10YR6/6	7.5YR6/8	LS	VFSG	FR	LO	SC
	43-75	ABg2	10YR6/4	10YR6/6	7.5YR6/8	SiCL	VFSG	FI	LO	SA
	75-104	Btg	10YR6/2	10YR5/3	7.5YR6/8	SL	VFSBK	FR	VHA	SD
	104-155	Bg1	10YR7/3	10YR5/4	7.5YR6/8	LS	VFSG	LO	LO	SD
	155-175	Bg2	10YR5/4	10YR5/3	7.5YR6/8	CL	VFBK	FR	SHA	SG
	175-200	2Btg	10YR5/2	10YR2/2	7.5YR6/8	C	CBK	FI	HA	

Determined at field condition.

Note: Abbreviation were according to FAO (2006)

Keys: Textural Class: CL=clay loam.

Structure: FBK=Fine Angular Blocky, VFBK=Very Fine Angular Blocky, and FSBK= Fine Subangular Blocky

Consistency: S=Sticky, VS=Very Sticky, SST=Slightly Sticky, Ha=Hard, SHA= Slightly Hard, VHA=Very Hard, and EHA=Extremely Hard.

Boundary Form: WC=Wavy Clear, WG=Wavy Gradual, WD= Wavy Diffuse, IG=Irregular Diffuse, SD= Smooth Diffuse

Morphological properties of the soils of Hauki 1 series (RBH2)

The morphological characteristics of the soils of RBH2 “Pedon P3 and P4” were presented in Table 2 (plates 4 and 5). The soils have shown evidence of development, because of its established B and C horizon with developed structures. The soils were deep with poor drainage influenced by the over flowed water from the surrounding river Sokoto. Matrix colour of the soil’s hue were taken both in dry and moist conditions; the hues were 10YR throughout the profiles of the two pedons, except for differences in value and chroma down the profiles. Pedon P3 and P4 have dull yellow orange (10YR6/4 dry) in their surface -horizons, changing to bright yellow brown (10YR7/6 dry) P3 and yellowish orange (10YR7/8) P4 in the subsurface (C horizon). Mottling occurs from the top soil down the profiles with abundance of many to common mottles in most layers of gleyed horizon of both P3 and P4. Colour of the mottles was bright brown (7.5YR6/8) due to the characteristic seasonal flooding which do occur from August to October of each year and associated seasonal wetting and drying conditions. According to FAO (2000), bright brown mottles colour usually indicates that the soil has good drainage.

The soils have textures of sandy loam to loam but predominantly sandy loam. A similar result was reported by Njoku (2018), who worked on the floodplain of Abakaliki. The author stated that soils with high content of sand and silt with low clay content were liable to erosion. Soil structure of pedon P3 ranged from very fine weak angular blocky at the surface to very fine weak sub angular blocky at the subsurface. P4 have structure of weak sub angular blocky to fine weak sub angular blocky in the surface and subsurface changing to fine single grain or granular.

Kefas *et al.* (2016) reported similar results. The pattern of the structure is not the same within the two pedons and this could be attributed to the nature of how materials were being deposited seasonally. There was clear indication that the soils were young and progressive soil structural development; has started from surface with weaker structure, changing to the subsurface horizon with stronger soil structures. These soils were derived from mostly alluvial deposits and some colluvial materials.

The soil consistency under moist condition is friable in the surface and loose to firm in the subsurface while, under dry condition it is slightly hard at the surface to soft at the middle changing to lose consistency at the subsurface in P3. The friable and slightly hard consistency under moist and dry condition may be due to the high content of sand with lower silt at the surface (Table 2). The firm to hard consistency in the soils is attributed to the higher content of silt with lower sand at the subsurface. In pedon 4 the consistency under moist condition were friable in its surface and subsurface but loose at the depth of 67-87cm because of high sand content. Under dry condition the consistency is hard at the surface and changing to lose consistency at 67-87cm to slightly hard consistency at the subsurface. The irregular consistency of the two pedons from surface to subsurface might be attributed to the distribution pattern in sand/silt with depth. The horizon boundary characteristics (width) of pedon 3 were abrupt at the surface over clear and diffuse at the subsurface with wavy and smooth topography at the surface and subsurface respectively. Pedon 4 has gradual surface over diffuse subsurface with smooth and wavy topography at the surface and subsurface respectively.



Plates 4 and 5: Profile Pits of Hauki 1 series (RBH2) Pedon P3 and P4 showing different horizon designations

Morphological properties of the soils of Dan Bolo series (RBH3)

Morphological properties of the soils of RBH 3 were presented in Table 2. Out of the six soil units RBH3 is located at the summit of the floodplain. The soils of RBH3 were perfectly well drained without evidence of mottling or gleying, with occurrence of few ant holes in the Ap and AB horizons as presented in Plate 6 and 7. Brady and Weil (2008), found these type of soils to be typically favourable for plant growth and certain land use practices such as grain crop and tree crop. The soils of RBH3 possesses excellent drainage, reducing the risk of waterlogging and making them ideal for agricultural activities because of their favourable drainage properties. Farmers can cultivate a variety of crops without the concern of water stagnation in these soil unit. The presence of ant holes in the Ap (topsoil) and AB (subsoil) horizons enhances soil aeration, nutrient cycling and soil structure improvement. According to Lavelle, P. (1997), ants play a role in the diversity of soil organisms. Their interactions with other soil

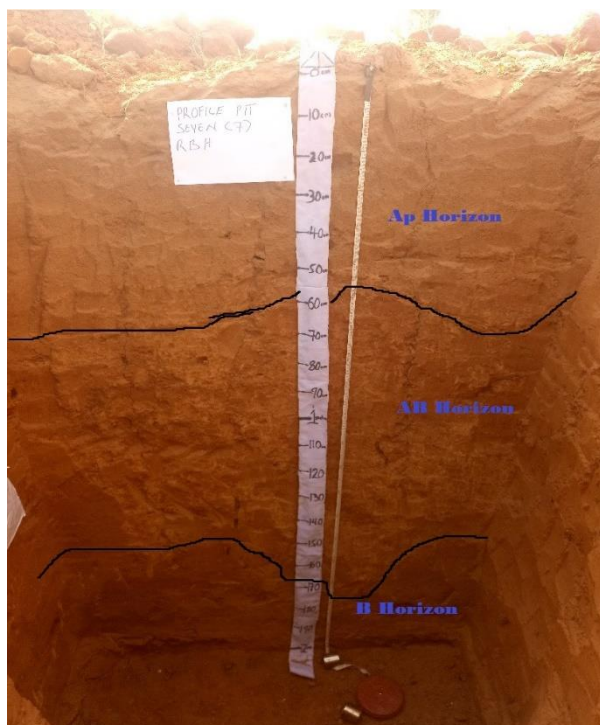
fauna and microorganisms can influence the composition and dynamics of the soil community and structure.

RBH3 covers approximately 10 % of the floodplain, it is classified locally as Dan Bolo Series (a name given to the area by the communities). Two profile pits were dug in the soil units and were named P5 and P6 (Plates 6 and 7). The matrix soil colour of P5 surface horizons (A) is brown (10YR4/6 dry) to dull yellowish brown (10YR6/4) moist, changing to bright brown (7.5YR5/6 dry) and bright reddish brown (5YR5/8 moist) at the subsurface horizons. Pedon P6 had dull yellowish brown (10YR5/4 dry) to dark brown (10YR3/4 moist) at top horizon while overlying bright reddish brown (5YR5/6dry) to bright brown (7.5YR5/6 moist) at subsurface. The change in colour of Pedon P5 from brown (surface) to bright brown (subsurface) is an indication that eluviation/illuviation processes had taken place. While in P6 the subsurface bright reddish brown to bright brown colourations may be due to reduction of haematite to goethite which is brownish in colour, and this

is in accordance with the work of Nsor *et al.* (2014).

Texturally the soils were sandy loam in all horizons of the Pedons except in the first layer (Ap) horizon of P6 which is loamy sand. The textural properties indicate that the soil have better infiltration when compared with other soil units studied in the floodplain, because of its high content of sand. The pedons have fine crumb structures at the surfaces over very fine weak angular blocky at the sub surface. The consistence of the pedons were non-sticky (wet) to lose (dry) at

the surfaces while slightly sticky (wet) to Soft (dry) at their subsurface horizons. The slight stickiness in the subsurface horizons were due to the presence of high amount of clay in the horizon compared with that in surface layers. The horizon boundary characteristics were irregular diffuse and wavy diffuse at the surface horizon of P5 and P6 respectively, while at the subsurface it has wavy diffuse and irregular gradual for both Pedons.



Plates 6 and 7: RBH3 (P5) and RBH3 (P6) Profile Pit

Morphological properties of the soils of Mahijin Riji series (RBH4)

The morphological characteristics of the soils of RBH4 “Pedon P7 and P8” were presented in Table 2 (Plate 8 and 9). The soils were deep upto 200cm. Matrix colour of the soil were Hue 10YR throughout the profiles of the two pedons, except for differences in value and chroma across the profiles. Pedons P7 has matrix colour of dull yellowish brown (10YR5/3 dry) at surface to bright yellowish brown (10YR6/6) and dull yellow orange (10YR6/3) in the subsurface. Pedon P8 has brownish grey (10YR5/1 dry) at its surface to greyish yellow brown (10YR6/2) in the subsurface. The variation in surface colour of the pedons is due to the influence of topography, parent material and organic matter content.

Mottling and gleying were observed in abundance of few to many from the surface and subsurface horizon layers of both pedons. Bouma & Dekker (2003), observed that

mottling and gleying in floodplains can impact agriculture by influencing soil drainage and fertility. Mottling is characterized by spots of different colours due to varying moisture levels from fluctuating water saturation. Gleying, on the other hand, suggests waterlogging and reduced oxygen availability. Both conditions may hinder root development and nutrient uptake in plants. Pedon P7 had a colour of bright reddish brown (5YR5/8) while P8 had bright brown colour (7.5YR5/6), an evidence that Goethite FeOOH (yellow) had been reduced to lepidocrocite FeOOH (reddish brown) in the profile due to redox reaction. The mottling is as a result of seasonal flooding of the soils which occurs mostly from late August to October of each year and associated seasonal wetting and drying nature of the floodplain. According to Osunde *et al.* (2001), the oxidation state of iron, manganese and sulphur in the soil strongly affects their solubility and colour, which explains the

brown, grey, reddish, blue, black and yellow mottles often seen in seasonally waterlogged hydromorphic soils.

The soils have fine angular blocky structure at the surface and changes to very fine single grain (granular) to very fine angular blocky structure at the subsurface of both P7 and P8. The texture of both pedons fluctuates irregularly across the profile having clay at the surfaces and clay at their deep sub-surfaces. The clay at the subsurface is due to lithological discontinuity (significant change in particle size).

The texture varies from silty clay, sandy loam, and loamy sand within the subsurface of the pedons, the fluctuation is due to the repeated deposition of sediment in periodic floods. These agree with the study of Buji *et al.* (2017) which states that the fluctuation in the textural class of soil signifies the nature of valley bottom soils, where different materials were deposited constantly. Soil consistency of both pedons at moist stage were firm at the surfaces and changes to friable at the subsurface horizons to extremely firm at the

lower sub-horizons; while soil consistency at dry level is hard at the surface changing to soft at the subsurface and extremely hard at the lower bottoms of the horizons of both pedons, the irregularity in the consistency from hard, soft, changing to extremely hard is because of the irregular fluctuation of soil texture and lithological discontinuity in the soils. The soils were formed from alluvial materials with no evidence of erosion hazard. Also, few vertical cracks were on the faces of the pedons up to 50 cm depth (see Plate 8). The presence of cracks suggests the possibility of 2:1 smectites clay mineral content within the soil. The horizon boundary characteristics (width) of Pedon 7 is diffuse at the surface over abrupt at the subsurface with wavy and smooth topography at the surface and subsurface. Pedon 8 has diffuse surface over diffuse subsurface with smooth and wavy topography at the surface and subsurface respectively.



Plate 8: Profile P7 RBH4 and **Plate 9:** Profile P8 RBH4

Morphological properties of the soils of Rabah series (RBH5)

The morphological properties of RBH5 P9 and P10 (Plates 10 and 11) were presented in Table 2. It covers 54ha (32 %) of the area, having the largest extent, that is why the name Rabah series was given to it. The horizon designations of RBH5 P9 were Ap-ABg-Bg1-Btg1-Btg2-2Bg2-2Btg2 while those of P10 were Ap-Bg1-Bg2-Bg3-Bg4-Btg1-Btg2, the two pedons have similar designation, all having Ap, Bg and Btg designations. The only difference is that Pedon P9 has lithological discontinuity at subsurface of 2Bg horizon which leads to variations in soil texture, structure, and composition. These variations influence water retention, drainage, and nutrient availability (Brady and Weil, 2008). Understanding lithological discontinuity is crucial for effective land use planning. It helps in identifying areas suitable for agriculture, construction, or other purposes based on soil properties.

The colour pattern of the soil matrix of P9 is irregular, ranging from dull yellowish orange (10YR6/4 dry) at surface to dull yellowish brown (10YR5/3, dry and 10YR5/4, moist) mid-subsurface to reddish brown (5YR4/6 dry) and greyish yellow brown (10YR5/2 moist) deep subsurface. Strong gleization might be the reason of change of colour from yellow (surface) to reddish brown (subsurface) of the pedons. Yellow, red or black colouration in soil is as a result of iron oxide minerals (Yakubu, 2006). RBH5 P10 has orange (5YR7/8, 7.5YR6/6 and 7.5YR6/8) mottles in the gleyed surface horizons and bright reddish brown (5YR5/6) mottles at its subsurface gleyed horizon. The mottles were observed in abundance of many, common and few, which is an indicative of poor drainage status occasioned by seasonal flooding. Similar results were observed by

certain floodplain soils of south eastern Nigeria (Moorman and Van de Wetering, 1985) and in the Sokoto-Rima Floodplains of North-western Nigeria (Noma, 2005).

Texturally the soil is clay in the surfaces of both pedons, loam at their mid-subsurfaces and clay at the deep-subsurfaces. The high percentage of clay and silt content might probably be one of the reasons that caused the soils poor drainage. Structurally, the soils have medium angular blocky structure in the surface of P9 grading to fine single grain to very fine angular blocky in the subsoil. The structure of P10 is well developed, it ranges from coarse sub angular blocky in the first surface (25cm) grading to medium sub angular blocky structure to medium angular blocky in the subsoil. The result is in agreement with the work of Yakubu *et al.* (2008). Consistency of soils in RBH5 soils were irregular ranging from very sticky (wet) and hard (dry), slightly sticky (wet) and slightly hard (dry), extremely sticky (wet) and extremely hard (dry) to sticky (wet) and hard (dry) in both pedons, the differences in the content of clay and silt is responsible for degree of stickiness and hardness of the pedons. The boundary in the surface horizon of pedon 9 had gradual boundary from surface and smooth boundary at subsurface. Horizons of P10, has smooth gradual boundary form in the surface changing to wavy diffuse and smooth gradual in its subsoil



Plate 10: RBH5 Profile 9 (P9) and **Plate 11:** RBH5 Profile 10 (P10)

Morphological properties of the soils of Hauki 2 series (RBH6)

The morphological characteristics of the soils of RBH5 P11 and P12 (Plate 12 and 13) were presented in Table 2. The soils were deep with poor drainage influenced by the over flowed water from the surrounding river Sokoto. Matrix colour of the soils were hue 10YR throughout the profiles of the pedons, except for differences in its Value and chroma across the profiles. Pedons P11 and P12 have dull yellow orange (10YR6/3, 7/3, and 6/4 dry) in their surface horizon (about 60 – 70cm thick) becoming dull yellowish brown (10YR5/4, 4/3 and 5/3 dry) in the subsurface of P11 and dull yellowish brown (10YR5/4 and 5/2 dry) in the subsurface of P12.

Mottling occurs from the surface soil down the profiles with abundance of many to common mottles in most layers of gleyed horizon of both P11 and P12. Mottle colouration of bright yellowish brown (10YR7/6) and bright brown (7.5YR6/8) is due to the characteristic seasonal flooding which occur from August to October of each year and associated alternate seasonal wetting and drying conditions. These results agree with the work of Noma (2005). The two soils have gleying properties at their surface and subsurface horizons and this might be due to the reduced conditions caused by the seasonal saturation of the soils. Similar result was obtained by Ibanga and Nsokpo (2001)

where they stated that wetland soils have gley and pseudo-gley horizons, where mottles and concentrations of re-oxidized compound occurs. These gley or pseudo-gley horizons were found either near the surface or at depth depending on the seasonal wetting and drying regime.

The textures of the soil fluctuate irregularly down the profile. Pedon 11 (P11) texture changes from loam at surface to loamy sand, clay, sandy loam, loamy sand, silty loam and clay at their subsurfaces. The clay found at the deep sub-horizon is as a result of lithologic discontinuity encountered. The irregularity of texture is attributed to the physiographic position of the soil (floodplain) and it agree with findings of Buji *et al.* (2017), who stated that soil texture in valley bottom (floodplain) fluctuates irregularly within their profiles, due to seasonal cycle of deposition of materials. The trend of texture for P12 was similar with pedon P11.

Soil structure of P11 ranges from fine angular blocky to fine sub angular blocky at surface to coarse single grain and fine single grain at the subsurface grading to fine angular blocky at the deep subsoil. P12 has structure of fine angular blocky to very fine subangular blocky in the surface, changing to very fine single grain at the subsurface, grading to coarse angular blocky. There is a clear indication that progressive soil structural development A to B

horizon was form, showing evidence of soil development. The soils were mostly derived from alluvial deposits and some colluvial materials. The soil consistency of P11 under moist condition is friable in surface and loose to firm in the subsurface while under dry condition it is loose at the top surface to slightly hard at the middle changing to loose/hard consistency at the lower subsurface. P12 consistency under moist condition is friable in their surface, firm in its subsurface grading to loose/firm consistency at its lowest subsoil. The changes of consistency in the two pedons from surface to subsurface might be

attributed to the decrease and/or increase of sand/clay content with depth.

Pedon 11 (P11) has horizon boundary characteristics of smooth gradual, wavy gradual, wavy diffuse, smooth gradual, irregular diffuse, wavy gradual to wavy diffuse boundaries. Pedon P12 has boundaries of smooth topography in all its horizon with diffuse, clear, abrupt, diffuse, gradual and diffuse widths respectively. Other features identified in these pedons were concentration of Fe-Mn concretion at Apg horizon of p11 and Btg horizon of P12, medium cracking observed at Btg1 (P11) and ABg2 (P12) of the soil units.

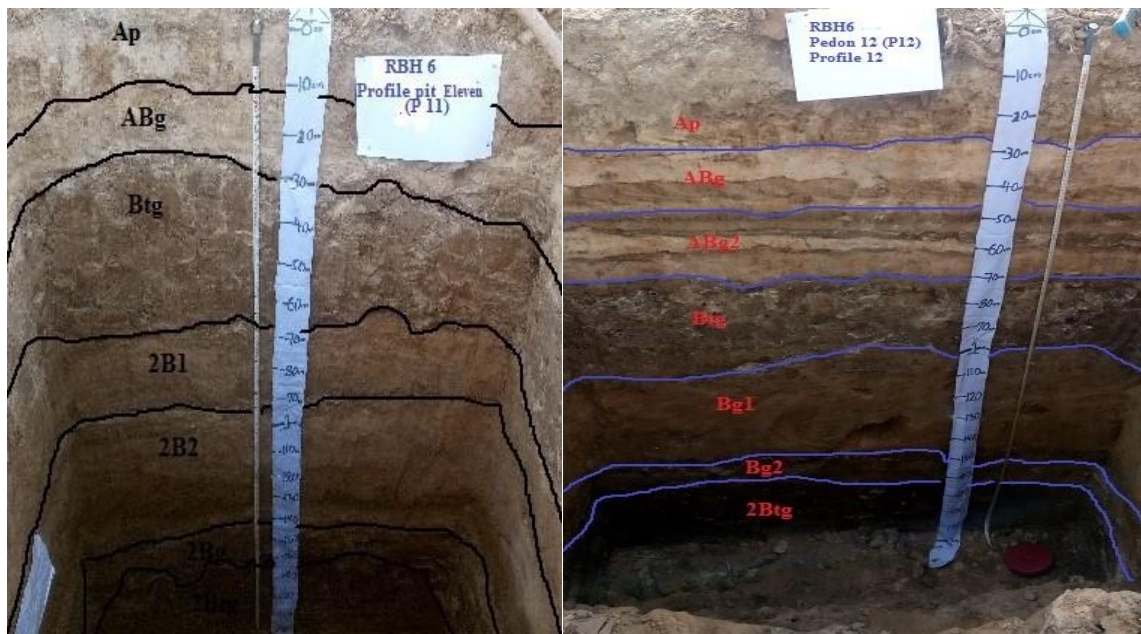


Plate 12: RBH6 Profile 11 (P11) and **Plate 13:** RBH6 Profile 12 (P12)

SUMMARY

Six soil mapping units RBH1, RBH2, RBH3, RBH4, RBH5 and RBH6 were identified on the basis of soil colour, surface soil texture and slope.

One of the most important morphological features of the soils of Rabah floodplain were gleying which occurs in all its soil units with the exception of RBH3 horizons. Gleyed horizons of these soils were mostly dark grayed coloured. The gleization is as a result of saturation with groundwater for long enough periods to develop reducing conditions

resulting in gleyic properties which suggests waterlogging and reduced oxygen availability. These conditions may hinder root development and nutrient uptake in plants. Mottles colour of orange (7.5YR6/8), (7.5YR6/6), bright reddish brown (5YR5/8), yellow orange (7.5YR7/8) and bright yellowish brown (10YR7/6) were observed in gleyed horizons due to the characteristic seasonal flooding which occur from August to October of each year and associated seasonal wetting and drying conditions. Mottling, characterized by spots of different colors due to varying moisture levels,

were observed in abundance of many, common and few, which is indicative of poor drainage status of the soils. Another important morphological property observed in the soils is the wide variability in their matrix soil colour, texture and structure, due to the fluctuating seasonal flooding, a situation where yearly addition and removal of materials occur, which eventually lead to nutrient redistribution, soil aeration reduction, crop selection, water management and pest and disease risk. Another feature observed is the occurrence of lithological discontinuity in Pedon P7, P9, P11 and P12 of Rabah floodplain soils, indicating differences in the parent material from which the horizons were formed. Soil erosion mostly through runoff were found in the surface. Accumulation of subsurface clay horizon (Bt) as evidence by illuvial process were recorded in most pedons. Another peculiar morphological characteristic noticed in the floodplain soil is the cracking due to the shrinkage and swelling of the high activity clay.

Structurally, RBH 1, 2, 4, 5 and 6 have structures that ranged from fine angular blocky (surface) to very fine angular blocky at the subsurface with wet consistency ranging from sticky at the surface, and slightly sticky at the subsurface, while RBH3 had fine crumb structures at the surfaces over very fine angular blocky at the sub surface. The consistence of the pedons were non-sticky (wet) to lose (dry) at the surfaces while slightly sticky (wet) to soft (dry) at their sub surface horizons.

CONCLUSION

From this study the following conclusion were drawn: Gleization and mottling were characteristic nature of floodplain soils. Repeated flooding events (a situation where

yearly addition and removal of materials is constant) result in wide variability in their matrix soil colour, texture and structure of alluvial soils, causing an irregular distribution of soil layers. Another feature observed is the occurrence of lithological discontinuity in Pedon P7, P9, P11 and P12 of Rabah floodplain soils, indicating differences in the parent material from which the horizons were formed.

In general, floodplains are known for experiencing seasonal flooding, as well as mottling and gleying, which can have different agricultural implications. One implication is nutrient redistribution, as floodwaters can distribute nutrients and affect soil fertility. Another implication is that mottling and gleying indicate waterlogging, which can create anaerobic conditions that might impact the availability of nutrients for plants. Persistent flooding can also hinder soil aeration, which can affect root respiration and nutrient uptake by crops, potentially leading to stunted growth and lower yields. Farmers might need to select flood-tolerant crops or adjust their planting schedule to optimize yields based on flood and dry periods. Furthermore, recurrent flooding may contribute to soil erosion and sedimentation, diminishing topsoil quality and reducing agricultural productivity. The presence of lithological discontinuity can result in variations in soil texture, structure, and composition, influencing water retention, drainage, and nutrient availability. Effective water management, such as the implementation of drainage systems or adoption of water conservation practices, is crucial to mitigate the impact of flooding on crops in floodplains.

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