



COMPARATIVE ASSESSMENT OF CHARACTERIZED AND CLASSIFIED SOILS OF NORTH-CENTRAL NIGERIA (REVIEW)



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Abstract

The review was conducted to comparatively assess the characterized and classified soils of North Central Nigeria. Five research articles were selected which reflect on the characterization and classification of soils of Minna, Jos, Lafia, Makurdi, and Ilorin. The findings of the review show that the horizons of the soils of the different locations have a near similarity in color, textural class, and horizon boundaries. The review shows that soils of Makurdi and Ilorin are dominated by sand particles while the soils of Jos, Minna, and Lafia are dominated by finer particles (silt and clay). The soil pH was observed to vary from strongly to moderately acidic in soils of Jos and Ilorin while that of the soils of Lafia, Makurdi, and Minna ranges from strongly acidic to neutral. The review observed that organic carbon content of the soils of Ilorin and Lafia are higher when compared with that of the soils of Makurdi, Jos, and Minna. The percentage base saturation was higher in soils of Lafia, Minna, and Makurdi while it was low in soils of Ilorin and Jos as reported. The selected soils of Makurdi, Minna, and Ilorin as classified shows similarity at suborder category known as ustalfs while selected soils of Minna and Jos are similar at great group level known as haplustepts. However, there is also similarity between selected soils of Makurdi and Lafia at suborder category known as aqualfs.

Keywords: Classified Soils; North-Central Nigeria; Comparative Assessment; Textural Properties

Introduction

Soil properties vary in spatial and temporal directions, and such variation depicts systematic changes as a function of the geology and derived landforms (Burke, 2002), soil parent materials (Koojman *et al.*, 2005) and soil management practices (land use) (Amusan *et al.*, 2006). Soils have diverse morphological, physical, chemical and biological properties. As a result, they differ in their responses to management practices, their inherent ability to deliver ecosystem services, as well as their resilience to disturbance and vulnerability to degradation (FAO, 2017). Characterization and classification of soils have therefore paramount importance in using those resources based on their capability to manage them in sustainable manner. Soil information obtained through systematic identification and grouping can be used for effective planning of different land uses, as they provide information related to potential and constraints of the land (Lufega and Msanya, 2017). Soils are usually characterized by using relevant physical, chemical and morphological properties inherent in them. It has been reported by Idoga *et al.* (2005) that soil as a natural resource cannot be properly managed without proper understanding of its characteristics.

According to Boul *et al.* (2003) soil classification consists of organization of knowledge, which ease in remembering properties, enhancing understanding of relationships, ease of technology transfer and communication between scientist and end users. The classification of soils is usually based on soil properties described in terms of diagnostic horizons, identified properties and materials, which to a greater extent could be measurable in the field. The selection of diagnostic characteristics considers their relationship with soil forming processes. Thus, an understanding of related soil forming processes contributes to a better characterization of soils; however,

not used as a distinguishing criterion. Soil characterization, classification and evaluation are the first or primary indicators for establishing soil database, as proper understanding of soil resources are indispensable for judicious use of land resources (Jagdish *et al.*, 2009; Udoh and Lekwa, 2014).

The combination of soil characterization and classification provides valuable information and understanding of the physical, chemical, mineralogical and biological properties of the soils that alleviate the adverse effect of soil degradation and aid precision agriculture (Sharu *et al.*, 2013; Ukut *et al.*, 2014). Soil characterization provides the basic information necessary to create functional soil classification schemes and to assess soil fertility to unravel some unique soil problems in an ecosystem (Tenga *et al.*, 2018). In many areas, including the North Central Nigeria, the availability and acquisition of the information is a challenge since limited information has been generated relating to nutrient levels and their variations in the soils. The North Central Nigeria represents a high potential agricultural area. It is part of the area that produces yam, rice, groundnut, melon, sorghum, millet, sesame, cassava and Bambara nuts in large quantity.

For appropriate decision making on sustainable use and management of soils and for improving agricultural production, there is need for comparative assessment for the characterized and classified soils of the study areas to determine their level of similarity and also to facilitate communication and transfer of knowledge to all end users of soil information, including farmers, extension staff and decision makers.

Materials and Methods

This paper reviews on characterization and classification of some soils of Makurdi (Idoga, 2014), Jos (Hassan *et al.*, 2015), Ilorin (Ogunwale and Isa, 2004), Lafia (Kyat and Idoga, 2018), and Minna (Nwaloka *et al.*, 2019) in North Central Nigeria. The review observed that the study areas lie within: latitude 7° 50' and 7° 60' N and longitude 8° 25' and 8° 40' E for Makurdi, latitude 9° 31' 54" N and latitude 9° 31' 21" N and longitude 6° 35' 53" and 6° 35' 55" E for Minna, latitude 8° 30' and 10° 10' N and longitudes 8° 20' and 9° 30' E for Jos, Latitudes 7° 19' 28" and 7° 55' 45" N and Longitudes 8° 30' 56" and 8° 18' 20" E for Lafia, and latitude 8° 20' 44" and 8° 30' 22" N and longitude 4° 25' 05" and 4° 40' 55" E for Ilorin. The mean annual rainfall ranges from 1000 to 1300 mm and the mean annual temperature ranges from 22 °C to 35 °C. The review observed that the North Central of Nigeria falls within the Guinea Savanna vegetation zone and it is dominantly an agrarian zone.

The reviews observed that the researchers (Idoga, 2014; Hassan *et al.*, 2015; Ogunwale and Isa, 2004; Kyat and Idoga, 2018; Nwaloka *et al.*, 2019) applied standard procedure in horizon description and soil sample collection. The samples were subjected to routine analysis using standard laboratory procedures and the following were determined particle size distribution, bulk density, pH, organic carbon, total nitrogen, available phosphorus, Ca, Mg, K, Na, and CEC. Base saturation and effective cation exchange capacity were calculated as stated by the researchers (Idoga, 2014; Hassan *et al.*, 2015; Ogunwale and Isa, 2004; Kyat and Idoga, 2018; Nwaloka *et al.*, 2019).

The soils were classified using United States Department of Agriculture (USDA) Soil Taxonomy system and the World Reference Base (WRB) (FAO/UNESCO) system for soil classification as stated by the researchers (Idoga, 2014; Hassan *et al.*, 2015; Ogunwale and Isa, 2004; Kyat and Idoga, 2018; Nwaloka *et al.*, 2019).

Findings and Discussion

The finding from the review shows that the morphological properties of the soils indicated that the colours were predominantly dark reddish brown with differences in hue among horizons of soils of Jos Hassan *et al.* (2015); dark grayish brown, grayish brown, strong brown, reddish yellow, and yellowish red among horizons of soils of Minna (Nwaloka *et al.*, 2019); red, dark reddish brown, yellowish red, dark brown, brown, and dark grayish brown among horizons of soils of Ilorin (Ogunwale and Isa, 2004); and light reddish brown, strong brown, brown, yellowish brown, dark, very dark brown, olive gray, light gray, pale yellow and dark grayish brown among horizons of soils of Makurdi (Idoga, 2014). However, Kyat and Idoga (2018) did not report on the colour variation among horizons of soils of Lafia. Hassan *et al.* (2015) reported that variation among soils colours of Jos resulted from physiographic position and differences in degree of profile development. It was observed that Idoga (2014); Kyat and Idoga (2018); Nwaloka *et al.* (2019) reported that drainage influenced the soil colour of Makurdi, Lafia, and Minna. This is in conformity with the report of Gerrard, (1981) and Esu *et al.* (2008) that drainage condition and physiographic position influence the observable change in the soil colour. The grayish coloration in some of the horizons of soils of Makurdi was an indication of imperfectly or poorly drained soil (Idoga, 2014). Hassan *et al.* (2015) and Nwaloka *et al.* (2019) reported that

redoximorphic features were evident within sub-horizons of soils of Jos and Minna. It was observed from the review that there are mottles in some horizons of soils of Jos, Minna, and Makurdi which is an indication of poor drainage. The review reveals that the soil textural classes of the horizons were predominantly sandy clay, loamy sand, sandy clay loam among soil profiles of Makurdi as reported by Idoga (2014); sand, sandy clay loam, sandy loam among soil profiles of Ilorin as reported by Ogunwale and Isa (2004); sandy clay loam, clayey loam, loamy, sandy loam among soil profiles of Lafia as determined by Kyat and Idoga (2018); clay, clayey loam among soil profiles of Jos as reported by Hassan *et al.* (2015); and silty loam, sandy loam, loamy, clay, sandy clay loam, loamy sand, sandy loam among soil profiles of Minna as reported by Nwaloka *et al.* (2019). The textural classes of the soils of Makurdi, Ilorin, Minna, and Lafia portray a near similarity which could be attributed to the similarity in parent material, climatic factors, and vegetation. This is in conformity with the report of Brady and Weil (2002) on effect of parent material, climatic factors, and vegetation on soil texture. The soil structure as observed from the review was dominated by granular, sub angular blocky in soils of Ilorin; massive structureless, crumb, granular, sub angular blocky in soils of Minna; granular, crumb, sub angular blocky in soils of Makurdi; sub angular blocky in soils of Jos and Lafia. Kyat and Idoga (2018) reported that sub angular blocky structure could be as a result of high organic clay contents of the soil. The review also showed that the boundaries were mostly clear and wavy, abrupt and wavy, clear and smooth, gradual and wavy among horizons of soils of Minna as reported by Nwaloka *et al.* (2019); clear and wavy, diffuse and clear, diffuse and smooth, clear and irregular among horizons of soils of Ilorin as reported by Ogunwale and Isa (2004); gradual and smooth, diffuse and smooth, gradual and wavy among horizons of soils of Makurdi as reported by Idoga (2014).

Table 1: Morphological properties of soils of Jos

Horizon	Depth (cm)	Munsell colour		Mottle		Consistency				Boundary	Miscellaneous Observation
		Moist	Dry	Colour	Texture	Structure	Wet	Moist	Dry		
Basaltic parent materials											
Profile No:BST 01											
Ap	0-35	5YR 3/3	5YR 4/6	-	C	2msbk	SP	Fi	Sh	gs	Many fine-medium roots; common hard fine gravel, common fine tubular pores, few empty fine medium termite/ant holes
Bw1	35-60	2.5YR ¾	2.5YR 4/6	-	C	2msbk	SSPS	Fi	Sh	cs	Few fine tubular pores; few medium-coarse roots; many fine hard Mn gravel, Clay cutans along pore
Bw2	60-88	2.5YR ¾	2.5YR 4/6		CL	1fsbk	SP	Fi	Sh	cs	Few fine roots; few fine tubular pores, many medium-hard Fe/Mn concretions.
Bt1	88-130	2.5YR ¾	2.5YR 3/6		C	2msbk	SP	Fi	Sh	ds	Few fine-medium roots; irregular common medium hard Fe/Mn concretions; common fine tubular pores.
Bt2	130-170+	2.5YR ¾	2.5YR 3/6		C	2msbk	SSPS	Fi	Sh	-	Very few fine roots; common soft to slightly hard Fe/Mn concretions; common very fine pores.
Profile No: BST02											
Ap	0-16	5YR ¾	-	-	CL	2msbk	SP	Fi	S	CS	Many fine roots, many fine few-medium pores; few ant nests
Bt1	16-70	2.5YR ¾	2.5YR 3/6	-	C	2msbk	SP	Fi	H	CS	Many fine roots; many fine-medium pores; vertical cracks, many medium ant nests.
Bt2	70-117	10YR ¾	2.5YR 3/6	7.5YR 4/8	C	2msbk	SP	Fi	H	CS	Many fine roots, many fine pores; few fine Fe/Mn concretions
Bc	117-152	5YR ¾	-	-	C	2msbk	SSPS	Fi	H	CS	Few fine roots; many medium-coarse Fe/Mn concretions; few medium weathered basaltic boulders.
C	152-175+	5YR ¾	2.5YR 3/6	-	C	2msbk	SP	Fi	H	-	Few fine roots; many medium soft Fe/Mn concretions; many medium-coarse partially weathered basaltic parent materials.

Source: Hassan *et al.*, 2015

Table 1: Morphological properties of soils of Jos cont

Horizon	Depth (cm)	Munsell colour		Mottle		Consistency					Miscellaneous Observation
		Moist	Dry	Colour	Texture	Structure	Wet	Moist	Dry	Boundary	
Basaltic parent materials											
Profile No: BST 03											
Ap	0-37	5YR ¾	-	-	C	msbk	SSPO	Fi	S	Gs	Many fine-medium pores; many fine-medium roots; common ant/termites nests.
Bw1	37-100	5YR ¾	-	-	C	2msbk	SP	Fi	H	Cw	Many fine pores; few fine soft iron nodules.
2BC1	100-110	5YR ¾	-	-	C	2msbk	-	Fi	-	-	Partially weathered basaltic materials.
2BC2	110-143	5YR ¾	-	-	C	2msbk	SP	Fi	H	Cs	Common medium pores.
2Cr	143-190	5YR 3/3	-	-	C	2msbk	SP	Fi	H	-	Many coarse partially weathered basaltic materials.
Profile No: BST 04											
Ap	0-15	5YR 3/3	-	-	C	1fsbk	SPO	Vfr	S	Cs	Many fine pores; many fine-medium roots; few termites/ant nests.
Bw1	15-110	5YR ¾	5YR 4/6	-	C	2csbk	SP	Fi	H	Ds	Many fine-common pores; many fine roots; many medium Fe/Mn concretions; few termites' nests.
Bw2	110-156	5YR ¾	5YR 4/6	-	C	2msbk	SP	Fi	H	Cg	Many fine pores; few medium-coarse Fe/Mn concretions; partially weathered basaltic boulder of medium-coarse size.

Source: Hassan *et al.*, 2015

Table 2: Morphological properties of soils of Ilorin

Horizons	Depth (cm)	Munsell colour (moist)	Texture	Structure	Boundary	Miscellaneous features
Pedon 1 (Upper slope) Plinthic Dystrustalf						
Ap	0-34	5YR 3/2	S	g	Cw	Common medium and few fibrous roots.
Bt	34-67	2.5YR 4/6	SCL	sbk	Ds	Very few fine roots and very few coarse roots; few coarse manganiferous nodules.
Bc	67-112	2.5YR 5/6	SCL	sbk	-	Few fine fibrous roots; few yellowish mottles; common coarse manganiferous nodules.
Bc2	112-175	2.5YR 4/8	SCL	sbk	-	Few coarse roots; common coarse manganiferous nodules; water table below
Pedon 2 (Middle slope) Typic Plinthustalf						
Ap	0-24	5YR 3/2	S	g	Cw	Common medium and few coarse fibrous roots
AB	24-62	5YR 4/3	S	g	Ci	Common medium fibrous roots; common coarse manganiferous nodules.
Btc	62-115	5YR 4/4	SL	sbk	Dc	Few medium coarse roots; abundant coarse manganiferous nodules.
Bc	115-165	5YR 4/6	SC	sbk	-	Few medium fibrous roots; abundant coarse manganiferous nodules.
Pedon 3 (Lower slope) Psammentic Alaquept						
Ap	0-20	10YR 3/2	S	g	Ds	Common coarse fibrous roots.
A	20-40	7.5YR 3/2	S	g	Cw	Common medium fibrous and few coarse roots.
AC	40-75	7.5YR 5/4	S	g	-	Common fine fibrous roots and few coarse fibrous roots; (false) water table below.

S= sandy, SCL= sandy clay loam, SL= sandy loam, SC= sandy clay, g= granular, sbk= sub-angular blocky, cw= clear and wavy, ds= diffuse and smooth, ci= clear and irregular, dc= diffuse and clear

Source: Ogunwale and Isa, 2004

Table 3: Morphological properties of soils of Minna

Pedons	Horizons	Depth (cm)	Colour (moist)	Mottles (moist)	Textural Class	Structure	Consistency			Boundary	Roots
							Dry	Moist	Wet		
CHA 1											
Pedon 1	Ap	0-23	10YR 3/2 (VDGB)	10YR 5/4 (YB)	SiL	Ms	v.h	Fi	st	cw	2fmrt
	Bw	23-54	10YR 3/2 (DGB)	10YR 5/4 (YB)	SL	Ms	v.h	Fi	s.st	-	1frit
Pedon 3	Ap	0-17	10YR 3/2 (VDGB)	10YR 5/4 (YB)	L	Ms	h	Fi	s.st	cw	2frit
	2C	17- 66	10YR 3/2 (DGB)	-	SL	Sg	s	Lo	n.st	-	2frit
CHA 2											
Pedon 2	Ap	0-28	7.5YR 4/4 (B)	-	SL	2m cr	s	v.fr	n.st	aw	2mrt
	Bt1	28-104	5YR 4/6 (YR)	-	SL	2m sb	h	Fi	s.st	cw	1mcrt
Pedon 7	Bt2	104-166	5YR 4/6 (YR)	2.5YR 3/6 (DR)	CL	2mc sb	h	Fi	st	-	2frit
	Ap	0-17	10YR 5/2 (GB)	10YR 5/4 (YB)	SL	1m cr	lo	Lo	n.st	cs	2fmrt
	AB	17-32	10YR 5/2 (GB)	10YR 5/4 (YB)	SL	1m sb	s	Fr	n.st	cw	2frit
	Bt1	32-93	10YR 5/3 (B)	10YR 5/4 (YB)	SCL	2mc sb	h	Fi	v.st	Gw	-
Pedon 9	Bt2	93-126	10YR 5/3 (B)	10YR 5/4 (YB)	C	2mc sb	h	Fi	v.st	Gw	-
	Bt3	126-173	10YR 5/4 (YB)	10YR 5/6 (YB)	C	2mc sb	h	Fi	v.st	-	-
	Ap	0-18	10YR 4/3 (B)	-	SL	2m gr	s	Fr	n.st	Cw	2mrt
	AB	18-33	10YR 4/4 (B)	-	LS	2m sb	s	Fr	n.st	Aw	2fmrt
	Btv	33-103	7.5YR 4/4 (B)	5YR 4/6 (YR)	SCL	2m sb	h	Fi	sl.st	Aw	1mrt
	Ct	103-170	7.5YR 6/6 (RY)	5YR 5/8 (YR)	L	2m sb	h	Fr	st	-	1mrt
CHA 3											
Pedon 6	Ap	0-29	7.5YR 4/4 (B)	-	SL	1fm gr	lo	v.fr	n.st	As	2fmrt
	Bt	29-85	7.5YR 5/6 (RY)	5YR 4/6 (YR)	SCL	2m sb	H	Fi	st	Gw	1mrt
	Btv	85-148	5YR 5/6 (YR)	5YR 4/6 (YR)	SCL	2m ab	H	Fi	st	Gw	-
	BC	148-185	5YR 5/6 (YR)	5YR 4/6 (YR)	CL	2mc sb	H	Fi	st	-	-
CHA 4											
Pedon 4	Ap	0-16	10YR 4/2 (DGB)	-	SL	1m gr	lo	Fr	n.st	As	1frit
	AC	16-41	10YR 5/4 (YB)	-	SL	1m sb	lo	Fr	n.st	Cw	1frit
	Cr	41-143	10YR 5/2 (GB)	10YR 5/3 (B)	SL	2m gr	H	Fi	n.st	-	-
Pedon 8	Ap	0-26	7.5YR 4/6 (SB)	-	SCL	2mc sb	H	Fi	st	Cw	1frit
	Bw1	26-105	5YR 4/6 (YR)	5YR 4/6 (YR)	SCL	2c sb	H	Fi	v.st	Cw	-
	Bw2	105-173	5YR 4/6 (YR)	5YR 4/6 (YR)	SCL	2m sb	H	Fi	v.st	-	-

Colour: VDGB= very dark grayish brown, DGB= dark grayish brown, SB= strong brown, RY= reddish yellow, YR= yellowish red, YB= yellowish brown, GB= grayish brown. Texture: SL= sandy loam, LS= loamy sand, SCL= sandy clay loam, SiL= silty loam, CL= clay loam, C= clay. Structure: 1= weak, 2= moderate, f= fine, m= medium, c= coarse, gr= granular, Ms= massive structureless, cr= crumbly, sb= sub-angular blocky, ab= angular blocky. Consistency: h= hard, v.h= very hard, fi= firm, v.fi= very firm, fr= friable, v.fr= very friable, st= sticky, sl.st= slightly sticky, v.st= very sticky, n.st= non-sticky. Boundary: Cs= clear smooth, Cw= clear wavy, As= abrupt smooth, Aw= abrupt wavy, Gw= gradual wavy. Roots: 1= few, 2= common, 3= many, f= fine, m= medium, c= coarse, rt= root

Source: Nwaloka *et al.*, 2019

Table 4: Morphological properties of soils of Makurdi

Horizons	Depth (cm)	Munsell colour (moist)	Mottle	Texture	Structure	Inclusions	Boundary	Remarks
Profile 1 Typic Paleustalf/ Eutric Luvisol								
A	0-12	7.5YR ¾	-	LS	1fgr	Cfr	Gs	-
B	12-25	7.5YR 4/6	-	SL	1fsbk	Cfr	Gs	-
Bt1	25-56	5YR 4/6	-	SCL	2msbk	Ffr	Ds	-
Bt2	56-98	5YR 5/6	-	SCL	3msbk	Ffr	Gs	-
Bt	98-165	5YR 5/8	-	SC	3csbk	-	-	Hard clay pan
Profile 2 Typic Paleustalf/ Eutric Luvisol								
A	0-8	7.5YR4/4	-	LS	1fcr	-	Gs	-
AB	8-36	7.5YR4/6	-	SL	1fsbk	-	Gs	-
Bt1	36-64	5YR 4/6	-	SCL	2msbk	-	Gs	-
Bt2	64-108	5YR 5/6	-	SCL	3msbk	-	Gs	-
Bt3	180-168	5YR 5/8	-	SC	3csbk	-	-	-
Profile 3 Arenic Endoaqualf/ Gleyic Luvisol								
A	0-28	10YR 2/2	10YR 5/8cif	SL	2fcr	Mfr	Gs	-
Bt1	28-46	10YR 5/6	7.5YR 5/8c2d	SCL	2msbk	Cfr	Gw	-
Bt2	46-81	2.5YR 6/4	7.5YR 4/6c2d	SCL	2msbk	Cfr	Gs	-
Bc	81-118	2.5YR 7/4	7.5YR 4/6c3d	SC	3csbk	-	-	Water table
Profile 4 Typic Endoaqualf/ Gleyic Luvisol								
A	0-30	10YR 2/1	-	SCL	3msbk	Mfr	As	Crack
Bt1	30-55	10YR 2/3	-	CL	3csbk	Ffr	Gs	-
Bt2	55-85	5Y 4/2	-	C	3csbk	-	Gs	-
Bt3	85-97	5Y 7/1	-	C	3csbk	-	-	-
Profile 5 Typic Endoaqualf/ Gleyic Luvisol								
Ap	0-28	10YR 2/3	10YR 5/8cif	SL	2fcr	Mfr	Gs	-
Bt1	28-43	10YR 5/4	7.5YR 5/8	SCL	2msbk	Ffr	Gw	-
Bt2	43-80	2.5Y 6/4	7.5YR 4/6c	SCL	2msbk	Ffr	Gs	-
Bt3	80-110	2.5Y 7/4	7.5YR 4/6	SC	-	-	-	Water table
Profile 6 Arenic Endoaquent/Eutric Gleysol								
A	0-16	10YR ¾	-	SL	1fgr	cfr	Gs	-
AB	16-40	10YR 5/4	-	S	1fgr	ffr	Gs	-
C1	40-76	2.5Y 4/2	-	S	1fgr	-	Gs	-
C2	76-106	2.5Y 7/4	-	S	1fgr	-	-	Water table

Textures: Is = Loamy Sand; Sl = Sandy loam; S = Sand; Scl = Sandy clay loam; Sc = Sandy clay; C = clay

Structures: Ifgr = Weak fine granules; Ifcs = Weak fine crumbs; 2fcs = moderate fine crumbs; IfSbk = Weak fine sub-angular blocky; 2msbk = moderate medium subangular blocky; 3msbk Strong medium subangular blocky; 3csbk = Strong coarse sub-angular blocky.

Inclusions: ffr = few fine roots; Cfr = common fine roots; mfr = Many fine roots.

Boundary: gs = gradual smooth; gw = gradual wavy; ds = diffuse smooth; as, abrupt smooth.

Source: Idoga, 2014

The findings from the soil physical properties as reviewed indicated that the soils of Ilorin and Makurdi had high percentage of sand when compared with that of Lafia, Jos, and Minna. The soils of Jos had the least percentage of sand among the locations compared. The sandiness of the soils could be attributed to a combination of sandy parent material, tropical climate and land use. These factors influence pedogenesis and soil properties (Wang *et al.*, 2001; Onweremadu *et al.*, 2011; Osujieke *et al.*, 2018). However, increase in sand fractions with depth in most pedons is an indication for weak profile development as reported by Nwaloka *et al.* (2019) in soils of Minna. Ogunwale and Isa (2004); Idoga (2014) reported that erosion and eluviation of finer particles contributed to the high sand content observed at the surface horizon of soils of Minna and Makurdi, respectively.

The review observed that percent silt ranged from 2.60 – 42.0 % among horizons of soil profiles of Lafia as reported

by Kyat and Idoga (2018), 8.0 – 54.0 % among horizons of soil profiles of Minna as reported by Nwaloka *et al.* (2019), 18.0 – 34.0 % among horizons of soil profiles of Jos as reported by Hassan *et al.* (2015), 2.0 – 16.0 % among horizons of soil profiles of Ilorin as reported by Ogunwale and Isa (2004), and 6 – 20 % among horizons of soil profiles of Makurdi as reported by Idoga (2014). Comparing the silt content of the various horizons soil profiles, it would be observed that the soils of Makurdi and Ilorin are highly weathered and pedologically mature due to low silt content. This is in conformity with the findings of (Ahn, 1993) that high weatherability leads to the formation of coarse textured soils. Morbeg and Esu (1991); and Kparamwang (1993) in the studies of soils in the Savanna region of Northern Nigeria mentioned the influence of Harmattan dust in contributing silt to soil. The review shows that the soils of Jos had high percent clay when compared with the soils of Lafia, Makurdi, Minna, and Ilorin. However, the soils of Ilorin had the least percent clay as compared. Hassan *et al.*, (2015) and Nwaloka *et al.* (2019) reported that soils with higher

fraction of clay down the profile depth resulted due to sorting, migration, and eluviation thereby forming argillic/kandic horizons. Ogunwale and Isa (2004) also reported that higher clay content observed in the subsurface horizons of soils may be attributed to illuviation and pedoturbation processes. Hassan *et al.*, (2015) reported parent material as the major factor affecting particle size distribution in the soils of Jos. This agreed with the report of Maniyunda and Gwari (2014) and Maniyunda *et al.* (2015) that attributed parent material as the major factor affecting particle size distribution in the soils of Nigeria environment.

The review observed that the horizons of soil of Lafia had a higher bulk density when compared with the horizons of soils of Makurdi, Minna, Jos, and Ilorin. Ogunwale and Isa (2004) reported that bulk density values were generally

higher for coarse textured soils than for finer textured soil. The sandy textured horizons had relatively higher bulk density values. Idoga (2014) reported that bulk density values show an increasing trend with depth in all the profiles. The reason for this difference could be due to the higher organic matter content. Nwaloka *et al.* (2019) reported that bulk density values of soils of Minna are considered favourable for plant growth and fall within the range of 1.00 – 1.60 g/cm³ for mineral soils as recommended by Akpan-Idiok *et al.* (2012). However, values of bulk density of soils of the study area as reviewed were lower than the critical limit range for root restriction (1.7- 1.8) g/cm³ (Soil Survey Staff, 1996). Bulk density variations are possibly due to changes in soil texture and organic matter distribution (Brady and Weil, 1999) as well as land use pattern.

Table 5: Physical properties of soils of Jos

Horizons	Depth (cm)	Sand (2000-50µm)	Silt (50-2µm)	Clay (<2µm)	Bulk density Mgm ⁻³	Porosity m ³ m ⁻³	Textural class
Profile No: BST 01 CHAHA							
Ap	0-35	30	20	50	1.049	0.396	Clay
Bw1	35-60	16	20	64	1.141	0.431	Clay
Bw2	60-88	44	22	34	1.304	0.492	Clay loam
Bt1	88-130	20	22	58	1.212	0.457	Clay
Bt2	130-170+	18	26	56	1.008	0.380	Clay
Profile No: BST 02 NITA							
Ap	0-16	38	34	28	1.171	0.442	Clay loam
Bt1	16-70	12	22	66	1.010	0.381	Clay
Bt2	70-117	20	22	58	1.008	0.380	Clay
Bc	117-152	26	26	48	1.010	0.381	Clay
C	152-175+	38	18	44	-	-	Clay
Profile No: BST 03 RA-HOSS							
Ap	0-37	10	26	64	0.978	0.369	Clay
Bw1	37-100	14	26	60	0.945	0.357	Clay
2BC1	100-110	24	28	48	-	-	Clay
2BC2	110-143	14	24	62	0.544	0.205	Clay
2Cr	143-190	14	32	54	0.913	0.345	Clay
Profile No: BST 04 TA-HOSS							
Ap	0-15	24	22	54	0.770	0.291	Clay
Bw1	15-110	20	22	58	0.602	0.227	Clay
Bw2	110-156	38	24	46	0.783	0.295	Clay
BC	156-190	38	26	36	0.641	0.242	Clay loam

Source: Hassan *et al.*, 2015

Table 6: Physical properties of soils of Lafia

Horizons	Depth (cm)	Bulk density (g/cm ³)	Sand Silt Clay			Textural class
			→ % ←			
Soil Unit I: Pedon 1 Chromic VerticEndoaqualfs/ AndicLuvisols						
A	0-15	2.73	69.2	2.60	28.2	SCL
B	15-30	2.82	25.5	40.6	33.9	CL
B1	30-87	2.87	39.1	42.0	18.9	L
B2	87-130	2.79	40.8	32.0	27.2	L
C	130-150	2.90	41.3	29.9	28.8	CL
Soil Unit I: Pedon 2 Chromic VerticEndoaqualfs/ AndicLuvisols						
A	0-30	2.93	73.5	15.7	10.7	SCL
A1	30-70	2.74	31.5	37.7	30.8	L
B	70-116	2.82	64.2	18.3	17.5	SL
C	116-199	2.84	61.3	25.0	13.5	SL
Soil Unit II: Pedon 3 AericVerticEndoaqualfs/ VerticLuvisols						
A	0-10	2.74	33.5	36.0	30.5	CL
AB	10-49	2.79	21.5	41.3	37.2	CL
B	49-99	2.94	35.1	36.4	28.5	CL
Bt	99-140	3.02	44.8	35.0	20.2	L
C	140-154	3.11	28.9	40.0	31.1	CL
Soil Unit II: Pedon 4 AericVerticEndoaqualfs/ VerticLuvisols						
A1	0-13	2.70	37.1	38.4	24.5	L
B2	13-57	2.98	34.8	42.0	23.2	L
B3	57-96	2.84	40.8	40.0	19.2	L
C	96-156	2.88	73.1	10.9	16.2	SL
Soil Unit III: Pedon 5 Chromic VerticEndoaqualfs/ VerticLuvisols						
A	0-28	2.52	40.8	18.2	40.0	SC
B	28-49	2.67	45.2	19.2	35.6	CL
Bt1	49-70	3.00	44.6	23.2	33.2	CL
Bt2	70-93	3.03	46.8	20.0	33.2	CL
Bt3	93-150	3.09	48.8	20.0	31.2	SCL
Soil Unit III: Pedon 6 Chromic VerticEndoaqualfs/ VerticLuvisols						
A	0-22	2.78	48.5	15.5	36.0	SC
B	22-67	2.77	44.6	21.0	34.4	CL
Bt1	67-93	3.20	48.2	20.8	31.0	SCL
Bt2	93-138	3.38	50.0	20.0	30.0	L
Bt3	138-160	3.40	39.7	22.3	38.0	L

Source: Kyat and Idoga, 2018

Table 7: Physical properties of soils of Ilorin

Horizons	Depth (cm)	Gravel (%)	Bulk density (g/cm ³)	Sand →	Silt % ←	Clay	Textural class
Pedon 1							
Ap	0-34	24.7	1.60	91.52	2.0	6.48	Sand
Bt	34-67	61.6	1.42	63.52	16.0	20.48	Sandy clay loam
Bc	67-112	64.6	1.20	65.52	6.0	28.48	Sandy clay loam
Bc2	112-175	71.4	1.01	73.52	2.0	24.48	Sandy clay loam
Pedon 2							
Ap	0-24	14.7	1.55	89.52	2.0	8.48	Sand
AB	24-62	84.6	1.32	89.52	4.0	6.48	Sand
Btc	62-115	93.8	1.25	79.52	4.0	16.48	Sandy loam
Bc	115-165	93.1	1.45	63.52	6.0	30.48	Sandy clay
Pedon 3							
Ap	0-20	14.5	1.45	91.52	2.0	6.48	Sand
A	20-40	30.0	1.55	89.52	2.0	8.48	Sand
AC	40-75	14.8	1.65	87.52	4.0	8.48	Sand

Source: Ogunwale and Isa, 2004

Table 8: Physical properties of soils of Minna

Pedons	Horizon	Depth (cm)	Sand	Silt kg/g	Clay	Textural Class	Silt/Clay	Bulk density (g/cm ³)
CHA 1								
Pedon 1	Ap	0-23	340	540	120	SiL	4.50	1.37
	Bw	23-54	520	360	120	SL	3.00	1.36
Pedon 3	Ap	0-17	480	420	100	L	4.20	1.38
	2C	17-66	580	320	100	SL	3.20	1.50
CHA 2								
Pedon 2	Ap	0-28	720	200	80	SL	2.50	1.47
	Bt1	28-104	420	180	400	SL	0.45	1.53
	Bt2	104-166	440	260	300	CL	0.87	1.55
Pedon 7	Ap	0-17	780	160	60	SL	2.67	1.49
	AB	17-32	700	100	200	SL	0.50	1.61
	Bt1	32-93	580	80	340	SCL	0.24	1.80
	Bt2	93-126	420	140	440	C	0.32	1.75
Pedon 9	Bt3	126-173	380	200	420	C	0.57	1.40
	Ap	0-18	740	160	100	SL	1.60	1.60
	AB	18-33	800	100	80	LS	1.50	1.53
	Btv	33-103	500	120	260	SCL	0.92	1.55
Pedon 6	Ct	103-170	500	300	200	L	1.52	1.39
	CHA 3							
	Ap	0-29	740	160	100	SL	1.60	1.73
	Bt	29-85	540	160	300	SCL	0.53	1.61
Pedon 4	Btv	85-148	500	180	320	SCL	0.56	1.57
	BC	148-185	400	240	360	CL	0.67	1.54
CHA 4								
Pedon 4	Ap	0-16	660	240	100	SL	2.40	1.52
	AC	16-41	680	160	160	SL	1.00	1.50
	Cr	41-143	550	250	200	SL	1.25	1.54
Pedon 8	Ap	0-26	460	200	340	SCL	0.59	1.45
	Bw1	26-105	600	140	260	SCL	0.54	1.65
	Bw2	105-173	540	160	300	SCL	0.53	1.56

Source: Nwaloka *et al.*, 2019

Table 9: Physical properties of soils of Makurdi

Horizons	Depth (cm)	Sand	Silt %	Clay	Bulk density (g/cm ³)
Profile 1 Typic Paleustalf/ Eutric Luvisol					
A	0-12	80	13	7	1.20
B	12-25	77	12	11	1.25
Bt1	25-56	70	10	20	1.35
Bt2	56-98	64	12	24	1.42
Bt	98-165	58	12	30	1.45
Profile 2 Typic Paleustalf/ Eutric Luvisol					
A	0-8	78	12	10	1.25
AB	8-36	75	13	12	1.28
Bt1	36-64	69	11	20	1.38
Bt2	64-108	60	12	28	1.45
Bt3	180-168	56	11	33	1.50
Profile 3 Arenic Endoaqualf/ Gleyic Luvisol					
A	0-28	77	14	9	1.15
Bt1	28-46	70	11	19	1.20
Bt2	46-81	62	12	26	1.22
Bc	81-118	57	13	30	1.24
Profile 4 Typic Endoaqualf/ Gleyic Luvisol					
A	0-30	58	13	29	1.29
Bt1	30-55	51	16	33	1.34
Bt2	55-85	41	16	43	1.35
Bt3	85-97	40	15	45	1.38
Profile 5 Typic Endoaqualf/ Gleyic Luvisol					
Ap	0-28	70	19	11	1.25
Bt1	28-43	65	20	15	1.28
Bt2	43-80	61	17	22	1.29
Bt3	80-110	57	12	31	1.29
Profile 6 Arenic Endoaquent/Eutric Gleysol					
A	0-16	83	10	7	1.10
AB	16-40	85	9	6	1.15
C1	40-76	88	7	5	1.18
C2	76-106	90	6	4	1.20

Source: Idoga, 2014

The review indicated that the soils of Jos and Ilorin are more acidic when compared with that of Lafia, Minna, and Makurdi. It was observed that soil pH(H₂O) was moderately acid in surface horizons to slightly alkaline within sub-horizons in Minna soils. Nwaloka *et al.* (2019) reported that the increased pH values in sub-horizons of Minna soils may be as a result of the accumulation of basic cations that have washed down in solution over time from top soils into sub-layers. Kyat and Idoga (2018) reported that pH of Lafia soils were predominantly slightly acid. He further stated that pH decreased with depth probably due to effect of nutrient bio-cycling. Idoga (2014) reported that the pH of Makurdi soils ranges from strongly to slightly acid. Hassan *et al.* (2015) reported that the soils of Jos are generally acidic (pH values mostly < 5.5). The pH values increase slightly down the profiles, in consonance with the less leached conditions of the area. Ogunwale and Isa (2004) reported that the soils of Ilorin are slightly acid. The surface horizons have relatively higher pH values. Higher pH values on the surface horizons have been attributed to relatively higher organic carbon level. Ogunwale and Isa (2004) further stated that it is generally accepted that the higher pH on the surface is due to cations being brought up from the sub-soil by the roots of plants and deposited on the surface in plant remains. The variation in soil pH of the study area could be attributed to the nature of the parent material, climate of the region,

organic matter and topographic situations (Abua *et al.*, 2010). According to Halving *et al.* (2005), pH range of 5.5 to 6.5 is the preferred range for most crops to thrive.

The review indicated that organic carbon values of Ilorin soils are generally low and decrease down the profile as reported by Ogunwale and Isa (2004). Hassan *et al.* (2015) reported that the organic carbon contents of the soils of Jos varies from low to moderate among horizons and decreased with increase in depth in all the pedons. Hassan *et al.* (2015) further stated that the low organic carbon content is attributed to paucity in vegetation, low return of crop residues and mineralization in the region. Idoga (2014) reported that the soil organic carbon content of Makurdi were very low to moderate among horizons of soil profile. He further stated that the depressional soils have more organic carbon. It was observed that horizons of soil profiles of Ilorin and Lafia had higher organic carbon when compared with the horizons of soil profiles of Makurdi, Jos, and Minna. The organic carbon content level of the surface horizons was predominantly low, moderate, high, low, and high for soils of Jos, Lafia, Ilorin, Minna, and Makurdi, respectively. However, land use activities such as livestock grazing, bush burning and the kind of arable farming in the area may have contributed to the difference in carbon content of the soils. Also, Gregorich *et al.* (1998) opined that cultural practices by the farmers and effect of erosion and deposition affect organic carbon distribution. For most Nigerian soils,

optimum crop production can be achieved when critical level of carbon content stands at about 10 g kg⁻¹ to 15 g kg⁻¹ (Esu, 1991). Carbon values below this critical level may encourage more leaching losses of basic cations into sub-soils.

The review reveals that among the compared locations where total nitrogen was reported, the horizons of the soil profiles of Lafia have high total nitrogen when compared with the horizons of soil profiles of Makurdi and Minna. It was observed that total nitrogen content of the surface horizons was predominantly high, very low, and moderate for soils of Lafia, Minna and Makurdi, respectively. Hassan *et al.* (2015); Ogunwale and Isa, (2004) did not

report on the result of total nitrogen among soil profiles of Jos and Ilorin, respectively. Kyat and Idoga (2004) reported that total nitrogen of soils of Lafia were low probably low due to the release from plant tissue, gaseous loss, and volatilization. Idoga (2014) and Nwaloka *et al.* (2019) reported that the total nitrogen was high in soils of Makurdi and Minna, respectively. The rate of nitrogen variation among the different soils is dependent on the availability of organic matter, the rate of volatilization, crop removal, and plant uptake. It has been observed that intense leaching and erosion due to high tropical rainfall result to N deficiency in tropical soils (Osujieke, 2017; Isirimah *et al.*, 2003).

Table 10: Chemical properties of soils of Jos

Horizons	Depth cm	pH		TEA Al ³⁺ + H ⁺	H ⁺	OC (%)	Ca	Mg	K cmolkg ⁻¹	Na	CEC	Base Sat (%)
		H ₂ O	CaC l ₂									
Profile No: BST 01 CHAHA												
Ap	0-35	5.3	4.9	2.3	1.0	0.54	0.90	0.026	0.266	0.045	12.2	10.0
Bw1	35-60	5.2	4.6	1.2	0.4	0.66	1.53	0.324	0.296	0.071	8.2	27.0
Bw2	60-88	4.6	4.2	2.2	0.8	0.68	1.26	0.501	0.197	0.039	4.3	46.0
Bt1	88-130	5.4	4.6	0.8	0.4	0.24	1.46	0.063	0.297	0.036	7.0	27.0
Bt2	130-170	5.4	4.6	0.9	0.4	0.41	0.89	0.097	0.164	0.055	9.6	13.0
Profile No: BST 02 NITA												
Ap	0-16	5.0	4.5	1.3	0.3	0.68	1.57	0.247	0.230	0.030	14.2	15.0
Bt1	16-70	5.4	4.8	1.6	0.5	0.60	1.42	0.314	0.294	0.082	14.8	14.0
Bt2	70-117	5.6	4.5	2.8	0.5	0.39	1.53	0.339	0.114	0.050	12.6	16.0
Bc	117-152	5.3	4.7	3.2	1.2	0.40	ND	0.195	0.228	0.066	10.2	05.0
C	152-175	5.2	5.0	3.3	1.2	0.41	2.68	0.287	0.147	0.084	12.4	26.0
Profile No: BST 03 RA-HOSS												
Ap	0-37	5.2	4.6	2.1	0.6	1.08	1.47	0.002	0.049	0.042	11.6	14.0
Bw1	37-100	5.2	4.2	1.3	0.4	0.33	1.35	0.028	0.068	0.124	9.2	17.0
2BC1	100-110	4.6	4.2	1.1	0.2	0.55	1.50	0.028	0.188	0.077	9.8	18.0
2BC2	110-143	4.9	4.5	2.2	0.7	0.51	1.30	0.176	0.246	0.032	9.0	20.0
2Cr	143-190	5.0	4.6	3.8	1.5	0.42	4.83	0.029	0.278	0.062	18.7	28.0
Profile No: BST 04 TA-HOSS												
Ap	0-15	5.5	5.4	1.4	0.6	1.23	1.19	0.152	0.181	0.045	8.5	18.0
Bw1	15-110	5.3	5.0	1.3	0.4	0.43	1.60	0.026	0.242	0.046	9.2	21.0
Bw2	110-156	4.8	4.7	1.7	0.8	0.31	1.22	0.115	ND	0.071	8.2	17.0
BC	156-190	5.6	5.2	1.2	0.2	0.41	1.48	0.152	0.027	0.102	5.0	15.0

CEC= cation exchange capacity, OC= organic carbon, TEA= total exchangeable acidity, BS= base saturation

Source: Hassan *et al.*, 2015

Table 11: Chemical properties of soils of Lafia

Horizons	Depth (cm)	pH		OC (%)	Av. P (mg/kg)	TN (%)	Ca	Mg	K	Na cmol/kg	TEA	ECEC	BS (%)
		KCl	H ₂ O										
Soil Unit I: Pedon 1 Chromic VerticEndoaqualfs/ AndicLuvisols													
A	0-15	4.58	5.63	1.60	4.10	0.70	3.80	3.40	0.34	0.36	1.08	8.63	92
B	15-30	4.50	5.76	1.10	4.50	0.56	3.76	3.30	0.34	0.38	1.03	8.97	89
B1	30-87	4.40	5.74	1.10	4.40	0.56	3.63	3.20	0.32	0.34	1.02	8.51	88
B2	87-130	4.87	5.84	0.87	4.20	0.56	3.61	3.18	0.32	0.34	0.99	8.44	89
C	130-150	4.53	5.92	-	4.15	0.49	3.52	3.06	0.29	0.33	0.72	7.92	91
Soil Unit I: Pedon 2 Chromic VerticEndoaqualfs/ AndicLuvisols													
A	0-30	5.07	7.15	1.44	4.80	0.56	4.10	3.60	0.36	0.40	1.12	9.52	88
A1	30-70	5.04	6.40	1.32	4.65	0.56	4.00	3.89	0.34	0.37	1.10	9.70	89
B	70-116	4.93	6.38	1.00	4.65	0.49	3.92	3.37	0.33	0.34	0.98	8.94	89
C	116-199	4.65	5.93	0.84	4.20	0.49	4.00	3.50	0.35	0.38	0.88	9.11	90
Soil Unit II: Pedon 3 AericeVerticEndoaqualfs/ VerticLuvisols													
A	0-10	4.49	5.91	1.62	4.40	0.59	3.86	3.30	0.30	0.34	1.13	8.93	87
AB	10-49	4.41	5.86	1.60	4.50	0.56	3.88	3.17	0.31	0.35	1.10	8.81	88
B	49-99	4.54	5.92	0.87	4.40	0.56	3.51	3.00	0.30	0.34	1.06	8.21	71
Bt	99-140	4.54	5.88	0.68	4.30	0.59	3.40	3.10	0.28	0.32	0.98	8.08	88
C	140-154	4.56	5.78	0.60	4.25	0.70	3.31	3.00	0.28	0.29	0.81	7.69	90
Soil Unit II: Pedon 4 AericeVerticEndoaqualfs/ VerticLuvisols													
A1	0-13	4.69	6.69	1.12	4.65	0.56	3.84	3.40	0.34	0.56	1.14	8.28	98
B2	13-57	5.60	6.62	1.07	4.50	0.56	3.74	3.18	0.32	0.36	1.04	8.64	88
B3	57-96	6.03	6.64	0.87	4.30	0.70	4.02	3.60	0.37	0.40	1.00	9.39	89
C	96-156	5.62	6.92	0.62	4.75	0.63	3.86	3.60	0.36	0.40	0.94	9.32	88
Soil Unit III: Pedon 5 Chromic VerticEndoaqualfs/ VerticLuvisols													
A	0-28	4.50	5.98	1.56	11.8	0.59	2.22	1.47	0.31	0.17	1.50	5.67	74
B	28-49	4.42	5.96	1.06	9.85	0.52	1.14	1.61	1.36	0.12	1.50	5.73	93
Bt1	49-70	4.33	5.68	0.92	9.12	0.51	1.10	1.54	0.84	0.10	1.35	4.37	81
Bt2	70-93	4.00	6.51	0.56	8.22	0.43	1.07	1.46	0.44	0.05	1.20	4.22	72
Bt3	93-150	4.12	5.12	0.62	8.0	0.04	1.05	1.33	0.48	0.02	0.88	3.76	77
Soil Unit III: Pedon 6 Chromic VerticEndoaqualfs/ VerticLuvisols													
A	0-22	4.88	5.99	1.03	10.5	0.10	2.81	2.53	0.30	0.16	1.50	7.30	79
B	22-67	4.62	5.88	1.00	9.01	0.09	1.92	1.29	0.28	0.12	1.65	5.26	69
Bt1	67-93	4.81	5.91	0.67	8.51	0.07	1.74	1.04	0.27	0.15	1.60	4.30	74
Bt2	93-138	4.72	5.82	0.58	8.50	0.05	1.53	0.89	0.24	0.10	1.80	4.36	63
Bt3	138-160	4.91	5.82	0.50	7.00	0.01	1.23	0.05	0.21	0.10	1.80	3.39	47

TN= total nitrogen, Av. P= available phosphorus, ECEC= effective cation exchange capacity, OC= organic carbon, TEA= total exchangeable acidity, BS= base saturation

Source: Kyat and Idoga, 2018

Table 12: Chemical properties of soils of Ilorin

Horizons	Depth (cm)	pH		Ca	Mg	K	Na cmol/kg	TA	CEC	OC	BS
		H ₂ O	KCl								
→ ← → % ←											
Pedon 1											
Ap	0-34	5.6	5.3	3.6	0.8	0.39	0.02	0.25	8.92	1.72	53.92
Bt	34-67	4.5	4.5	4.8	2.0	0.09	0.02	0.25	12.08	2.19	57.20
Bc	67-112	4.6	4.6	7.6	1.6	0.19	0.02	0.20	68.08	1.64	13.82
Bc2	112-175	5.0	5.0	6.8	3.2	0.23	0.03	0.20	29.16	1.52	35.19
Pedon 2											
Ap	0-24	6.0	5.1	4.0	1.6	0.13	0.03	0.20	10.20	1.68	56.47
AB	24-62	5.8	5.3	3.6	1.6	0.16	0.02	0.24	9.48	1.60	56.75
Btc	62-115	5.7	5.2	2.0	1.6	0.22	0.02	0.20	11.08	1.20	34.66
Bc	115-165	5.1	4.9	7.2	2.0	0.45	0.03	0.20	21.02	0.52	46.05
Pedon 3											
Ap	0-20	6.0	5.3	5.6	0.8	0.18	0.01	0.20	10.0	1.64	65.95
A	20-40	5.5	5.0	3.2	0.8	0.16	0.02	0.20	9.44	1.28	44.28
AC	40-75	5.6	5.0	2.4	0.8	0.14	0.01	0.24	9.08	0.32	36.89

TA= total acidity, ECEC= effective cation exchange capacity, CEC= cation exchange capacity, OC= organic carbon, BS= base saturation

Source: Ogunwale and Isa, 2004

Table 13: Chemical properties of soils of Makurdi

Horizons	Depth (cm)	pH (H ₂ O)	OC →	TN ←	Av.P (mg/kg)	Ca	Mg	K →mol/kg	Na ←	CEC	BS (%)
Profile 1 Typic Paleustalf/ Eutric Luvisol											
A	0-12	6.20	0.90	0.10	6.50	2.68	1.84	0.12	0.09	6.34	75
B	12-25	5.95	0.75	0.08	5.50	2.40	1.86	0.10	0.08	6.30	70
Bt1	25-56	5.80	0.50	0.05	4.00	2.36	1.94	0.14	0.09	6.68	68
Bt2	56-98	5.45	0.30	0.03	3.10	2.36	2.00	0.11	0.11	7.12	64
Bt	98-165	5.40	0.30	0.03	3.20	2.48	1.88	0.12	0.10	7.48	61
Profile 2 Typic Paleustalf/ Eutric Luvisol											
A	0-8	5.90	0.80	0.09	6.00	2.50	1.76	0.11	0.09	5.82	77
AB	8-36	5.86	0.60	0.05	5.11	2.16	1.96	0.14	0.11	5.60	78
Bt1	36-64	5.67	0.40	0.03	3.46	1.86	2.04	0.13	0.10	6.04	68
Bt2	64-108	5.80	0.30	0.03	3.00	1.90	1.88	0.12	0.11	6.14	65
Bt3	180-168	5.84	0.30	0.03	3.20	2.08	1.68	0.12	0.12	6.24	64
Profile 3 Arenic Endoaqualf/ Gleyic Luvisol											
A	0-28	6.21	1.64	0.18	9.20	4.28	2.40	0.14	0.11	7.80	87
Bt1	28-46	6.00	0.82	0.09	7.68	3.84	2.58	0.11	0.10	8.01	83
Bt2	46-81	5.84	0.50	0.06	6.88	3.20	2.12	0.12	0.12	8.68	64
Bc	81-118	6.05	0.30	0.05	6.94	3.60	2.46	0.14	0.12	9.10	69
Profile 4 Typic Endoaqualf/ Gleyic Luvisol											
A	0-30	5.72	1.65	0.18	12.80	4.68	2.58	0.20	0.12	8.20	92
Bt1	30-55	5.62	0.90	0.10	8.00	3.40	2.89	0.21	0.12	8.36	79
Bt2	55-85	5.42	0.50	0.05	6.50	2.80	2.90	0.21	0.10	8.88	67
Bt3	85-97	5.27	0.40	0.05	6.00	2.76	2.00	0.21	0.09	9.21	55
Profile 5 Typic Endoaqualf/ Gleyic Luvisol											
Ap	0-28	6.30	1.25	0.15	9.80	3.42	2.14	0.18	0.12	6.88	85
Bt1	28-43	6.05	0.65	0.07	8.60	3.26	2.26	0.16	0.12	6.78	86
Bt2	43-80	5.90	0.50	0.05	7.20	2.92	1.90	0.14	0.11	6.94	73
Bt3	80-110	5.98	0.03	0.03	6.80	3.08	1.98	0.16	0.12	7.06	76
Profile 6 Arenic Endoaquent/Eutric Gleysol											
A	0-16	5.75	0.84	0.08	5.20	1.20	0.87	0.11	0.11	3.68	62
AB	16-40	5.40	0.50	0.04	3.20	0.86	0.70	0.12	0.12	3.20	55
C1	40-76	5.20	0.30	0.03	3.00	0.84	0.64	0.10	0.10	2.86	58
C2	76-106	5.25	0.10	0.01	1.86	0.78	0.60	0.10	0.10	2.56	61

TN= total nitrogen, Av.P= available phosphorus, CEC= cation exchange capacity, OC= organic carbon, BS= base saturation

Source: Idoga, 2014

Table 14: Chemical properties of soils of Minna

Pedons	Horizons	Depth (cm)	pH (H ₂ O)	pH (CaCl ₂)	OC →	TN ←	Av. P (mg/kg)	Ca	Mg	K →	Na ←	TEA	CEC	BS (%)
CHA 1														
Pedon 1	Ap	0-23	5.85	5.45	9.18	1.15	4.38	5.12	0.55	0.07	0.25	0.80	6.90	86.8
	Bw	23-54	6.12	5.62	4.59	0.48	12.3	4.2	0.35	0.08	0.25	0.40	5.70	85.6
Pedon 3	Ap	0-17	6.62	5.89	2.39	0.42	5.95	3.82	0.64	0.10	0.32	0.40	0.60	81.3
	2C	17-66	6.64	5.72	5.39	0.48	3.68	5.38	0.64	0.09	0.31	0.40	7.30	87.9
CHA 2														
Pedon 2	Ap	0-28	6.37	5.60	4.49	0.48	3.33	1.50	0.36	0.05	0.21	0.60	3.20	66.3
	Bt1	28-104	6.24	5.97	3.79	0.39	1.75	3.52	0.43	0.10	0.31	0.40	5.40	80.7
	Bt2	104-166	6.31	5.98	2.98	0.39	2.45	3.76	0.39	0.10	0.29	0.60	5.80	78.3
Pedon 7	Ap	0-17	6.50	5.38	3.99	0.39	7.70	1.75	0.38	0.09	0.21	0.80	3.60	67.5
	AB	17-32	6.15	5.29	2.39	0.45	7.18	3.44	0.46	0.10	0.29	0.80	5.70	75.3
	Bt1	32-93	7.14	6.48	3.80	0.39	3.15	7.39	2.14	0.11	0.32	0.60	11.5	86.6
	Bt2	93-126	7.68	6.98	2.59	0.45	4.20	12.6	4.56	0.09	0.45	0.10	18.8	94.1
	Bt3	126-173	7.75	6.68	3.99	0.36	4.20	17.7	3.55	0.12	0.55	0.10	22.6	97.0
Pedon 9	Ap	0-18	6.37	6.03	4.59	0.62	5.25	4.08	0.67	0.16	0.21	0.40	5.60	91.4
	AB	18-33	6.42	6.00	4.20	0.62	3.33	3.91	0.55	0.08	0.23	0.60	5.40	88.3
	Btv	33-103	6.92	6.27	1.20	0.70	2.98	6.32	0.87	0.23	0.31	0.40	8.40	92.0
	Ct	103-170	6.45	5.74	1.80	0.53	2.80	2.19	1.54	0.12	0.43	0.60	9.60	44.6
CHA 3														
Pedon 6	Ap	0-29	6.22	5.54	2.99	0.48	3.68	2.68	0.28	0.25	0.24	0.40	4.10	84.1
	Bt	29-85	6.08	5.35	5.19	0.31	2.78	5.30	0.68	0.12	0.25	0.60	7.40	85.8
	Btv	85-148	6.24	5.67	4.19	0.34	3.33	6.81	1.44	0.12	0.23	0.60	9.60	89.6
	BC	148-185	6.40	5.75	4.39	0.28	3.68	9.17	3.05	0.09	0.33	0.60	14.3	88.4
CHA 4														
Pedon 4	Ap	0-16	5.75	5.23	3.99	0.36	16.1	2.19	0.48	0.08	0.57	0.80	4.60	72.7
	AC	16-41	6.17	5.33	3.99	0.59	3.15	3.56	0.36	0.07	0.20	0.80	5.60	74.8
	Cr	41-143	6.50	5.51	4.39	0.31	3.85	5.79	0.56	0.10	0.37	0.60	7.80	87.4
Pedon 8	Ap	0-26	6.67	6.03	5.40	0.56	3.85	4.89	0.54	0.10	0.25	0.10	6.80	85.0
	Bw1	26-105	5.98	5.58	3.79	0.64	2.98	5.50	0.68	0.08	0.22	0.80	7.70	84.2
	Bw2	105-173	6.25	5.74	3.20	0.42	2.98	5.61	1.30	0.07	0.21	0.60	8.60	83.6

TEA= total exchangeable acidity, TN= total nitrogen, Av. P= available phosphorus, CEC= cation exchange capacity, OC= organic carbon, BS= base saturation

Source: Nwaloka *et al.*, 2019

The review observed that available phosphorus when compared indicated that the soils of Makurdi were higher than that of the soils of Minna and Lafia. Hassan *et al.*, (2015); Ogunwale and Isa, (2004) did not report on the result of the available phosphorus among soil profiles of Jos and Ilorin. Nwaloka *et al.* (2019) reported that available phosphorus of Minna soils was low to moderate. Kyat and Idoga (2018) reported that the values of available phosphorus were relatively high and decreased with increasing depth. Idoga (2014) reported that available phosphorus varies from low to moderate in soils of Makurdi. The variation of P among the horizons could be attributed to the distributions of organic materials and P fixation within the pedons. Low instances of P values in most horizons of pedons under the studied locations may be associated with low carbon content within the horizons. Weil and Brady, (2016) stated that carbon is a major source of P in most soils.

The review observed that the total exchangeable bases (Ca^{2+} , Mg^{2+} , K^{+} and Na^{+}) of the soils of Makurdi, Lafia, and Ilorin are predominated with calcium and magnesium while soils of Jos and Minna are predominated by calcium. Osujieke *et al.* (2020) and Imadojemu *et al.* (2017) also observed the predominance of Ca^{2+} and Mg^{2+} in soils of Northern Nigeria. Ogunwale and Isa (2004) reported that high calcium values may be an indication that the soils have a high affinity for calcium and also that Ca^{2+} is more strongly more strongly bound to exchange sites than other cations. However, high Ca^{2+} values may be an indicative of parent material (Ojanuga and Awujoola, 1981). The soils were the values of K^{+} are low relative to Ca^{2+} and Mg^{2+} , hence the uptake of K^{+} may be affected.

The total exchangeable acidity as observed (TEA) had a range of 0.20 - 0.25 cmol/kg for soils of Ilorin as reported by Ogunwale and Isa (2004), 0.10 - 0.80 cmol/kg for soils of Minna as reported by Nwaloka *et al.* (2019), 0.8 - 3.8 cmol/kg for soils of Jos as reported by Hassan *et al.* (2015), and 0.72 - 1.80 cmol/kg for soils of Lafia as reported by Kyat and Idoga (2018). However, Idoga, (2014) did not report on the TEA of the soils of Makurdi. Ogunwale and Isa (2004) reported that total acidity values for the Ilorin soils are generally low. He further stated that low total acidity values are associated with high pH values and indicate low acid weathering in soils.

The review reveals that the soils of Ilorin had high cation exchange capacity when compared with the soils of Makurdi, Jos, and Minna. However, Kyat and Idoga, (2018) did not report on the CEC of soils of Lafia but reported on its ECEC. However, the CEC level of the surface horizons was predominantly moderate in soils of Jos and Ilorin while it was predominantly low at the surface horizons in soils of Minna and Makurdi. Ogunwale and Isa (2004) reported that soils of Ilorin have higher sub-surface values, as compared with surface values. This might be indicative of mineralogical nature and composition rather than the presence of organic carbon. Nwaloka *et al.* (2019) reported that the CEC of soils of Minna increased with soil depth probably due to increase in clay content with depth. The low value of CEC can be an index of low chemical weathering activity of the soil (Okusami and Oyediran, 1985) and high acidity. Hassan *et al.* (2011) also reported that the low CEC of the soil could be attributed to the nature of clay mineral (Kaolinite). Ojanuga and Awujoola, (1981) reported that

CEC is influenced by texture and nature of soil parent material, CEC being lower in coarser textured soils than in the finer textured soils.

The observation made from the review indicated that percentage base saturation of Makurdi and Minna soils were higher than that of Lafia, Jos and Ilorin when compared. It was reported that the percentage base saturation of the surface horizons was predominantly very low in soils of Jos, very high in soils of Lafia, Makurdi, Minna, and moderate in soils of Ilorin. Kyat and Idoga (2018) stated that base saturation status of Lafia soils could be linked to the active plant litter decomposition process, which incorporates cations from the litter into the soil surface. Nwaloka *et al.* (2019) reported the values of base saturation of Minna soils agrees with the results of Lawal *et al.* (2012) and (Afolabi *et al.*, 2014) that the soils of Minna. However, SSS, (2014) reported that soils with base saturation of greater than 50 % are regarded as fertile soils while soils with less than 50 % were regarded as non-fertile soils. In this regard the surface horizons of soils of Jos are infertile and as such require improvement. Soils with percentage base saturation rated from moderate to high (47 % to 98 %) could be linked to the active plant litter decomposition process, which incorporates cations from the litter into the soil surface (Malgwi *et al.*, 1986). High base status of the soils shows that basic nutrients may occur in available form for plant uptake despite low cation reserve in the soils (Aki *et al.*, 2014).

Soil Classification

The observation made from the reviews show that the Idoga (2014) classified soils of Makurdi as follows Typic Paleustalfs (Eutric Luvisols), Arenic Endoaqualf (Eutric Luvisols), Typic Endoaqualfs (Gleyic Luvisols), and Arenic Endoaquent (Eutric Gleysol). Nwaloka *et al.* (2019) classified soils of Minna as follows Aquic Haplustepts (Anthraquic Cambisols), Typic Haplustalfs (Haplic Luvisols), Typic Plinthustalfs (Haplic Plinthosols), and Lithic ustorthents (Cambic Leptosols). Kyat and Idoga (2018) classified soils of Lafia as Chromic Vertic Endoaqualfs (Andic Luvisols), Aeric Vertic Endoaqualfs (Vertic Luvisols). Ogunwale and Isa, (2004) classified soils of Ilorin as Plinthic Dystrustalf (Dystric Plinthisols), Typic Plinthustalf (Dystric Plinthisols), and Psammentic Halaquept (Dystric Fluvisols). Hassan *et al.* (2015) classified soils of Jos as Typic Haplustepts (Ferralic Acrisols) and Andic Haplustepts (Ferralic Acrisols).

The soils as classified using USDA soil taxonomy showed that the selected soils of Makurdi, Minna, and Ilorin are similar at sub order level known as ustalfs. Ustalfs are the Alfisols that have an ustic moisture regime (moisture is limited, but available, during portions of the growing season). Moisture moves through most of these soils to deeper layers only in some years. Many of these soils have or have had savanna vegetation, and some were grasslands. Most of the soils are used as cropland or for grazing. Ustalfs tend to form a belt between the Aridisols of arid regions and the Udalfs, Ultisols, Oxisols, and Inceptisols of humid regions. Ustalfs may be in areas of erosional surfaces or deposits of late-Wisconsinan age, but a great many, and characteristically those of warm regions, are on old surfaces.

There was also similarity as observed in selected soils of Makurdi and Lafia at sub order level known as aqualfs.

Aqualfs are the wet Alfisols. They are saturated close to the surface by ground water for a long enough period during the year to become devoid of oxygen (aquic conditions). Some are artificially drained. Their appearance is commonly characterized by a gray and red mottled color pattern (redoximorphic depletions and concentrations). Aqualfs occur in low landscape positions, such as flood plains, depressions, and broad flats. A few may be on side slopes where water seeps laterally over restrictive layers to the surface. Many Aqualfs are drained and used for cultivated crops. Rice is a common crop on the Aqualfs that have a thermic or warmer temperature regime as suggested by (Idoga, 2014; Kyat and Idoga, 2018).

The review shows that the soils as classified indicated that the selected soils of Minna (Nwaloka *et al.*, 2019) and Jos (Hassan *et al.*, 2015) are similar at great group level known as haplustepts while selected soils of Ilorin (Ogunwale and Isa, 2004) are similar to that of Minna and Jos at order level known as Inceptisols. Inceptisols have profiles that are weakly developed to meet the criteria for any of the other soil orders. As a consequence, Inceptisols include a diverse collection of soils. The feature common to all Inceptisols is a relatively weak degree of development. Inceptisols are most commonly characterized by a soil profile with an ochric (typically thin and/or light-colored) epipedon and a cambic (minimal soil development) subsoil horizon. Ustepts are mainly the more or less freely drained Inceptisols of subhumid to semiarid regions. They have an ustic moisture regime (moisture is limited, but available, during portions of the growing season). They receive dominantly summer precipitation. They formed mostly in Pleistocene or Holocene deposits. Some of the soils with steep slopes formed in older deposits. Haplustepts are the more or less freely drained Ustepts that are calcareous at some depth or have high base saturation (SSS, 2014). They commonly have an ochric (typically thin and/or light-colored) epipedon over a cambic (minimal soil development) subsoil horizon. Some have an accumulation of calcium carbonate in the subsoil. The native vegetation commonly was grass, but some of the soils supported trees. However, Idoga (2014) and Nwaloka *et al.* (2019) observed Entisols in the soils of Makurdi and Minna, respectively. Entisols typically have little or no development of soil horizons, other than a slightly darkened ochric (typically thin and/or light-colored) epipedon as a surface layer. Therefore, these soils are characterized not by the kinds of horizons that have formed but rather by their minimal degree of soil development.

Conclusion

The review reveals that there was variation in soil characteristics and similarity among different classified soils of the locations. The findings indicate that the soil structure varies among soils of the different locations. It was observed from the review that soils of Makurdi, Minna, and Ilorin were dominated by sand particles while the soils of Lafia and Jos were dominated by finer particles (silt and clay). The bulk density of the soils of the different locations was reported to be lower than the critical limit range for root restriction. The soil pH as observed shows that the soils of Ilorin were the most acidic while the soils of Minna were the least acidic. The soils of Ilorin and Lafia were high in organic carbon when compared with the soils of Makurdi, Jos, and Minna as been observed.

The CEC of the soils of Ilorin were higher than those of the soils of Makurdi, Jos, and Minna. The observation made from the review shows that percentage base saturation was predominantly low in soils of Jos, high in soils of Lafia, very low to high in soils of Ilorin, moderate to high in soils of Minna, and moderate to very high in soils of Makurdi. Kyat and Idoga (2018) did not report on the colour variation among horizons of the soils Lafia. Hassan *et al.* (2015) and Ogunwale and Isa did not report on the total nitrogen and available phosphorus of the soils of Jos and Ilorin. The unreported results will amount to limitation of soil information to land users.

The soils as classified using USDA soil taxonomy showed that the selected soils of Makurdi, Minna, and Ilorin are similar at sub order level known as ustalfs. There was also similarity in selected soils of Makurdi and Lafia at sub order level known as aqualfs. Aqualfs are the wet Alfisols. The soils as classified indicated that the selected soils of Minna and Jos are similar at great group level known as haplustepts while selected soils of Ilorin are similar to that of Minna and Jos at order level known as Inceptisols. However, Entisols was observed in the soils of Makurdi and Minna as classified.

Recommendations

Based on the reviews, the following recommendations have been made;

- Subsequent research on the pedological characteristics of soils should report on the morphological properties and all the results of the routine analyses. Hence, this will provide adequate soil information about the locations for the benefit of the land users.
- The Ilorin and Jos locations require liming materials to reduce their level of acidity and there is need to avoid the use of acid fertilizers.
- The soils of locations that are within the ratings of low to moderate in; CEC (Jos, Ilorin, Minna, and Makurdi), organic carbon (Jos, Lafia, and Minna), total nitrogen (Minna and Makurdi), and base saturation (Jos) requires to be incorporated with organic matter to enhance them.
- The soils that are similar at any level of USDA soil taxonomy require same management practices for their sustainability.

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Conflict of Interest

There is no conflict of interest

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