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Soil suitability evaluation of Babayau flood plain for selected arable crop cultivation in Ardo-kola, Taraba State, Nigeria

[1]Gisilanbe, S.A., [2]Musa, H., [1]Musa, U.A. and [2]Musa, S.A

[1]Department of Agronomy, Faculty of Agriculture, Taraba State University, Jalingo
[2]Department of Soil Science, Modibbo Adama University of Technology, Yola

Abstract

The study's objective was to characterize the soils and carry out suitability evaluation of floodplain soils in Ardo-Kola, Taraba State. Six (6) profile pits were dug from two physiographic units and the most predominant land use (woodland area and arable land area). Three (3) profile pits were dug on each of the identified units using standard dimension. Soil morphological results indicated that the soils were sub-angular blocky, strong to fine structure, very sticky, hard when dry and firm when moist in the woodland area. Colour ranged from pale brown 10YR (6/3) to dark greyish brown 10YR (4/2). Soils in the arable land area were mostly very sticky, firm when moist and hard when dried. The colour ranged from light yellowish-brown 10YR (6/4) to dark grey 10YR (4/1). Results of particle size distribution were sandy loamy and loamy sand across the pedons. Bulk density values ranged from 1.50 to 1.67gm/cm^3, and total porosity ranged from 37 to 43% respectively. The soils were generally moderately acidic to slightly acidic, organic carbon and total nitrogen was low (<2% and <0.15%), calcium and magnesium were rated medium (2-5cmol/kg and 0.3-1.0cmol/kg) respectively. Base saturation values were rated medium (50-80%) to high (>80%) across the pedons. Soil suitability result for the woodland area showed overall suitability for maize in pedon BYF1 was S3w (marginally suitable) with limitation in nutrient availability and suitable (S1) in pedon BYF5. Arable land area was also marginally suitable (S3) with limitation in oxygen availability except for pedon BYF4, which was not suitable (N) for maize cultivation. Woodland area was moderately suitable (S2) and suitable (S1) for the arable land area with limitation in texture except for pedon BYF 3 with limitation in oxygen availability. Rice production is encouraged in the arable land area while maize in the woodland area using fertilizers and organic materials to ameliorate low fertility limitations observed in the study area.

Keywords: Characterization; Soil Fertility; Floodplain; Soil suitability; Pedon

Corresponding Author's E-mail Address: gisilanbe27poksman@gmail.com: Phone: +2347063505330
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1.0. Introduction

Soil suitability evaluation is the process of making predictions of land performance over time based on specific types of uses (Rossiter, 1996). Nigeria is the most populous country in Africa, with a population of over 160million people. Its domestic economy is dominated by agriculture, which accounts for about 40% of the Gross Domestic Product (GDP) and two-thirds of the labour force. Agriculture supplies food, raw materials and generates household income for the majority of the people. In Nigeria today, the need to increase food production to feed the ever-increasing human population and diversify the country's export base crops is more recognized now than ever before. This has turned both farmer and government's attention to the exploitation of floodplains that are believed to have more agricultural potential than the upland soils (Esu, 1999).

Decisions on land use are being based on a comprehensive analysis of the production and potentials of natural resources such as climate, soil and hydrology. Land evaluation is critical in this direction as it provides information on the potentials and constraints of land for a defined land use type in terms of crop performance as affected by the physical environment. Soil suitability classifications are based on knowledge of crop requirements, prevailing conditions and applied soil management methods (Ande, 2011). Soil suitability classification quantifies in broad terms the extent to which soil conditions match crop requirements under a defined input and management (Jimoh, 2015). Assessing the suitability of land enables optimum performance and maximum productivity of the crop. The specific crop requirements will be calibrated with the terrain and soil parameters (Dent and Young, 1981). Land evaluation is a systematic process of identifying and measuring land qualities and assessing them for alternative kinds of use of the land. The broad principles of land evaluation involved comparing the requirements of land use with quality of land; thereby assessing the value of each type of land present for each land use (Dent and Young, 1981).

Land evaluation and soil evaluation can tell farmers how suitable their land is in terms of soil limitations, to specified land use and management practices. Floodplain soils constitute the backbone of arable crop production in the semi-arid and arid savannah agro-ecological zones where precipitation (rainfall) is limited for agricultural productivity. Floodplains are predominantly flat-floored inland valleys bordering or adjacent to the banks of major rivers and streams. They form part of a larger group called the wetland soils. The floodplains, also known as "Fadamas" in Northern Nigeria, have become very prominent because of their intensive agricultural production (Akamigbo, 2001). Agricultural development, a subset of economic development, implies a sustained increase in the level of production and productivity over a reasonable length of time and the subsequent

Improved wellbeing of farmers as reflected in their higher per capita income and standard of living. Rural development relates not only to a high increase in the level of production and productivity of all rural dwellers, including farmers, and a sustained improvement in their wellbeing, manifested by increased per capita income and standard of living, but also leads to a sustained physical, social and economic improvement of rural communities (Esu, 2005). The farmer's interest in the business of producing crops is mainly on how profitable it is to grow a particular crop and what amendments are necessary to optimize the productivity of the soil for the specified crop (Fasina and Adeyanju, 2006). The pressing demand for food and space from a growing population has created a competition for land. In many developing countries, Nigeria includes fuelwood, cash crops, timber for construction and grazing for livestock compete with food crops for space, not only on the better quality land but also on the marginal areas (Verheye, 2000). Farmers in Babayau floodplain have complained of the decline in crop yield while other crops seemed to perform better as they change the location for cultivating the crops. The farmers cultivate the soil continuously for several years with little or no fertilizers, and the suspect decline in land fertility. There is an increase in farmers cultivating the soils partly due to the floodplain's potentials to support arable crop production, which further puts pressure on the land resources. The major crops cultivated in the study area include maize, cowpea, rice, sorghum, groundnut and cassava. Many families depend on yield from the floodplain to feed their families and provide for other economic and household needs.

For many farmers, cultivating these crops is their main source of leaving and improving or reducing the quality of yields will directly affect their lifestyle. This study determined soil properties to evaluate soil suitability which is essential to farmers for more certainty and guide how best they will cultivate their crops, effectively and efficiently manage the land for optimum productivity. This study's objectives were to evaluate the soil's morphological properties, determine some soil physical and chemical properties, and evaluate the suitability of the soils for maize and rice cultivation in the study area.

2.0. Materials and Methods

2.1. Location of the study

The study was conducted in Jalingo, the State Capital of Taraba State, Nigeria. Jalingo is located between latitude $11^0 52' 11.57''$ N and longitude $11^0 19' 11.26''$ E, and it is situated in the northern guinea savannah zone of Nigeria.

2.2. Site selection

Before selecting the site, a reconnaissance survey was done to establish the terrain of the area. The pits were sited based on the area's physiographic units and based on the predominant land uses woodland area and arable land area. In siting the profile pits, the following were considered; the number of physiographic units, the best representative of the unit in the cultivated sites based on morphology and the accessibility to the profile points.

2.3. Fieldwork and sample collection

Six (6) profile pits were cited in the area, three (3) profile pits were dug each to represent the two physiographic units: the woodland area arable land area. The coordinates pedons of woodland are; $08^0$53'09.9" N; $011^0$21'05.0E (BYF1), $08^0$53'27.7" N; $011^0$20'47.8E (BYF5), $08^0$53'38.2" N; $011^0$20'12.8E (BYF6) with elevations of 188m, 182m and 180m respectively. While the coordinates for arable land are; $08^0$53'08.09" N; $011^0$20'45.3E (BYF2), $08^0$53'24.6" N; $011^0$20'08.0E (BYF3), $08^0$53'33.0" N; $011^0$20'15.0E (BYF6) with elevations of 184m, 191m and 182m respectively. The profile pits had varying depths due to the height of the water table in the study area. Profile pits were dug using the standard dimension of 2 X 1.5 X 2m according to the USDA (2014). Soil samples were collected in each of the pits' diagnostic horizons identified, and soil morphological properties were described according to FAO (2006). Twenty-eight (28) soil samples were collected, well labelled and placed in clean polythene bags described by Soil Survey Field and Laboratory Methods Manual (2014).

2.4. Soil sample preparation

The collected soil samples from the fields were air-dried, crushed and passed through a 2mm sieve for some soil physical and chemical analysis in the laboratory as described by the Soil Survey Field and Laboratory Methods Manual (2014).

2.5 Laboratory Analysis

2.5.1. Soil physical properties

Soil particle size distribution was determined by the Bouyoucos hydrometric method (Bouyoucos, 1965) as described by Jaiswal (2004) after destroying organic matter (OM) using hydrogen peroxide (H_2O_2) and dispersing the soils with Sodium Hexametaphosphate ($NaPO_3$). Soil bulk density was determined by the undisturbed core sampler method after drying the soil samples in an oven at 105^0C to constant weights as described by Jaiswal (2004). The oven-dried soil's mass will be divided by the total soil volume to obtain the bulk density (Black 1965). Also, Particle density was determined by using the pycnometer method (Blake and Hartge, 1986). Total porosity was calculated using the formula: $F = 1 - (Db/Dp) \times 100$

Where; F =Total Porosity

Db=Bulk density

Dp= Particle density

2.6. Soil chemical properties

Soil reaction (pH) of the soil was measured in a 1:2 soil and water suspension ratio using a glass rod and electrode pH meter (Black, 1965 as in Jaiswal, 2004). Electrical conductivity (EC) was determined using the same soil sample ratio from pH to determine EC, and its measurement was carried out using the EC meter. The Organic Carbon was determined using Walkley and Black (1934) by oxidizing the organic matter(OM) in concentrated sulfuric acid solution (0.1N H_2SO_4) and percentage of soil organic matter was obtained by multiplying percent soil

OC by a factor of 1.724 following the assumptions that OM is composed of 58% carbon. Total nitrogen was analyzed using the Kjeldahl digestion, distillation and titration method described by Black (1965). Available soil phosphorus was analyzed according to the standard procedure of Olsen *et al.* (1954) extraction method. The soil samples' exchangeable bases were determined by extracting with neutral ammonium acetate (NH_4OAc) (Black, 1965). The exchangeable potassium and sodium were determined via the flame photometric method. Percentage base saturation was determined in the laboratory using NH_4OA_C (Ammonium acetate) as described by Soil Survey Staff (2014). The following formula was used: % BS= (A/B) x 100 Where: A = NH_4OA_C Extractable Bases (C_a + M_g) (cmol (+) kg^{-1}).B = CEC – 7 (cmol (+) kg^{-1}).

2.7. Soil Suitability Classification

Soil suitability evaluation was conducted based on the principles of matching the land use requirement with the land quality, according to Kparmwang *et al*. (1998) and FAO (1995). The factors for rating soil requirement range from suitable (S_1), moderate suitable (S_2), marginally suitable (S_3) and not suitable (N). The principles of matching the soil use requirement with land qualities as described by FAO, 1995; Kparmwang *et al.,* 1998; Dada, 1989; and Nwaka and Kwari, 1993. The data obtained for both land characteristics and qualities of the land units and land use requirements were matched to give soil suitability classes (FAO, 1995). The matching produced suitability classes for each quality (Table 1). When combined, the extreme suitability class for the individual qualities gave the extent of limitation to productivity to be minor, moderate or severe. The extent of the combined limitations was used to produce the overall suitability class for each crop.

Table 2: Rating of Soil Use Requirement for Selected Crops

Land Quality	Diagnostic Factor	Unit	Factor Rating			
			S_1	S_2	S_3	N
(a) Maize						
Oxygen availability (g)	Drainage	Class	Well-drained	Mod. Well drained	Poorly drained	Very poorly drained
Nutrientavail. (a)	Reaction	pH	6-7	5.5-6	5-5.5,7.5-8	<5.6, >8
Nutrient Retention cap (n)	Base saturation	%	>70	50-70	30-50	<30
Rooting condition (r)	Depth	Cm	>120	50-120	30-50	<30
Soil workability(w)	Texture	Class	SL, L	SCL, SiL	LS, CL, SCL	SC, SiL, C
Soil workability (k)	Structure	Class	Mod. Well. Dev. Structure	Mod. Dev. Structure	Weakly dev. Struc.	Structureless
ErosionHazard(e)	Slope	%	0-2	2-4	4-6	>6
(b) Rice						
Oxygen availability (g)	Drainage	Class	Imperfectly drained	Moderately – well drained	Well drained; somewhat excessively drained	excessively drained
Nutrientavail. (a)	Reaction	pH	6.5-6.0, 6.5-7.0	5.5-5.0, 7.5-7.9	5.0-4.5, 7.9-8.2	<4.5, >8.2
Nutrient Retention cap (n)	Base saturation	%	>50	35-20	<20	-
Rooting condition (r)	Depth	Cm	>75	51-75	25-50	<25
Soil workability(w)	Texture	Class	SiC, C, SiCL,CL, Si, SiL	Fine C, SCL, SL, Loamy fine sand	LS, L coarse sand, fine sand	S, Coarse sand
Soil workability (k)	Structure	Class	Mod. Well. Dev. Structure	Mod. Dev. Structure	Structureless	-
ErosionHazard(e)	Slope	%	0-3	3-8	8-15	>15

Source: Sys *et al*. (1993, Modified)
Key: S_1=suitable, S_2=moderately suitable, S_3=marginally suitable, N=not suitable

3.0. Result and Discussion

3.1. Some morphological properties of soils in the woodland area

Table 2 represents the morphological properties of pedon BYF P1 (Lamurde Bridge), BYF P5 (Water Board) and BYF P6 (Runde) representing the woodland. Soils in BYF P1 were sub-angular blocky, strong to fine structure, very sticky very plastic, and hard when dry, very firm when moist. Atofarati *et al.* (2012) reported similar findings in the floodplain. Soils in Pedon BYF P1 were strong, fine and sub-angular blocky structured at 0-37cm depth observed similarly in P5 0-25cm depth. The soils were very sticky, very plastic, very firm when moist and very hard when dry. A similar trend was very firm, very hard when the soils were moist and dry respectively. This result may be due to the soil's sandy nature at the surface horizon as recorded in the work of Esu *et al.* (2008). The soil in pedon BYF P5 (Waterboard) consists of a strong, firm subangular blocky structure in all the depth. There were many and medium roots in the first horizon and also in the second horizon there were few and fine roots at the downslope of the pedon's horizon, these observations were similar to Atofarati *et al.* (2012).

The result of the soil structure and consistency are presented in table 2. Pedon BYF P6 indicated that the soils were sub-angular blocky, strong to fine structure at 0-25cm depth, strong to fine structure at 25-60cm, medium to moderate structure at 60-120cm depth respectively. The pedon showed the BYF P6 0-25cm depth were very sticky very plastic while 25-60cm depth, were very sticky and very plastic the soil was very sticky very plastic, firm and very hard when wet, moist and dry respectively. At 60-120cm depth of the pedon these results might be due to

increasing soil structure at the BYF P1, P5, and P6 due to clay and other soil moving down from the crest these activities increase soil structure and consistency. Similar results were observed by Hussaini (2011). The soil in BYF P6 sub-angular blocky with strong to fine structure at 0-25cm strong to fine structure at 25-60cm depth and fine to the strong structure at 60-120cm depth.
The soils' consistency was slightly sticky, slightly plastic firm to soft at the BYF (horizon 0-25cm) depth. At a depth of 25-60cm depth, the pedon was very sticky, very plastic firm to very hard respectively. The presence of wood ranging from few to fine and fine to medium characterized the pedon's horizons. This results indicated that wood penetration and soil inclusion activity might promote or decrease root movement similar were decreased by Shobayo *et al.* (2010), who reported that wood penetration resistance depends on many factors.

Table 2: Some Morphological Characteristics of Soil in the Woodland Area

Pedon	HD	Depth	Colour (dry)	(Moist)	Mottles	Texture	Structure Grade	Class	Type	Consistency	Inclusions
BYF P1	Ap	0-37	10YR 6/3	10YR 4/3	n	SC	S,	f,	s.b.k	wvs, vp, mvf, dh	rff
	A1	37-107	10YR 3/2	10YR 6/3	f	C	S,	f,	s.b.k	wvs, vp, mvf, dvh	rff
	A2	107-140	10YR 7/3	10YR 4/4	c	C	S,	f,	s.b.k	wvs, vp, mvf, dvh	n
	E	140-170	10YR 6/4	10YR 5/6	m	SC	S,	f,	s.b.k	wvs, vp, mf, dh	n
	C	170-200	10YR 7/4	10YR3/4	n	S	W	g		wns, np, ml, dl	n
BYF P5	Ap	0-25	10YR 4/2	10YR 6/3	n	C	S,	f,	s.b.k	wvs, vp, mvf, dvh	rmm
	A1	25-52	10YR 6/3	10YR 3/3	n	SC	S,	f,	s.b.k	wvs, vp, mvf, dvh	rff
	A2	52-103	10YR 7/2	10YR 3/1	n	C	S,	f,	s.b.k	wvs, vp, mvf, dvh	n
	E	103-120	10YR 4/4	10YR 5/3	f	C	S,	f,	s.b.k	wvs, vp, mvf, dvf	n
	C	120-160	10YR 8/1	10YR 6/4	mmcp	SC	S,	f,	s.b.k	wvs, vp, mvf, dvh	n
BYF P6	Ap	0-25	10YR 5/3	10YR 4/3	n	SC	S,	f,	s.b.k	wvs, vp, mf, dvh	rff
	AE	25-60	10YR 6/3	10YR 4/3	n	SC	S,	f,	s.b.k	wvs, vp, mvf, dvh	n
	E	60-120	10YR 6/3	10YR 4/4	n	SCL	m,	m,	s.b.k	wsls, slp, mf, ds	n
	Bt1	120-140	10YR 6/4	10YR 3/4	n	C	S,	f,	s.b.k	wvs, vp, mvf, dvh	n
	Bt2	140-170	10YR 6/4	10YR 3/2	cmp	C	S,	f,	s.b.k	wvs, vp, mvf, dvh	rfc
	C	170-187	10YR 8/2	10YR 5/6	n	S	W,	c,	s.b.k	wns, np, ml, dl	n

KEY: HD: horizon designation, mottles: n=none Texture: S=sand, SL = Sandy loam, SCL = Sandy clay loam, SC = sandy clay. Structure: Grade; w = weak, m = moderate, s = strong. Class; f= fine, m=medium, c=coarse. Type; sbk=subangular blocky. Consistency: wet; ns= non sticky, np = non plastic, sl= slightly sticky, sp= slightly plastic, vs= very sticky, vp= very plastic, moist; l= loose, vf= very friable, f= firm, vf= very firm, Dry; l= loose, s= soft, h=hand, vh= very hard. Inclusion: r=root; Abundance: f = few, c= common, m= many; Size: f= fine, m= medium, c= coarse, n= none.

Result for soil colour is presented in table 2: Soils in pedon BYF P1 were pale brown 10YR (6/3) when dry and brown 10YR (4/3) at 0-37cm depth. The soils were very pale brown 10YR (7/3) at 107-140cm depth when moist and dry. Yellowish-brown colour 10YR(7/3) was observed at 140-170cm depth both when dry and moist the higher clay content often observed in the surface horizon of many soils may be attributed to elevation pedoturbation processes these observations were similar to work of Malgwi *et al.* (2001). Pedon BYF P5 recorded dark greyish brown 10YR (4/2) colour when dry and moist, at the depth of0-25cm depth, the soils were pale brown 10YR (3/3). These results support similar trends as observed by Abdullahi *et al.* (2009).
Soils in pedon BYF P6 were 10YR (5/3) when dry and brown 10YR (3/2) when moist at 0-25cm depth very dark greyish brown 10YR (6/3) when moist at 25-60cm depth respectively when dry the soil at 60 – 120cm depth were pale brown 10YR (6/3) and 10YR(4/4) when moist, and few major fine mottles, the soil was dark yellowish-brown 10YR (6/4) when dry and light yellowish-brown 10YR (3/4) when moist with non-mottles120-140 cm depth. This soil colour trend might be due to the decrease of materials downslope, improving the soil structure, and reducing soil colour. A similar report was supported by Ayolagha and Opene *et al.* (2012).

3.2. Some morphological properties of soil in the arable land area

Table 3 represents some morphological properties of pedon BFY P4 (Jauro Gana), P2 (CBN) and P3 (Checkpoint) respectively, and this represents the arable land area. Pedon BYF P4 revealed that the soils were sub-angular blocky, strong to medium structure at 0-13cm depth. Also, the soils were very sticky, very plastic and firm when moist and hard when dried.
The soils had a strong structure at 13-27cm depth and were weak, coarse and sub-angular blocky structure. These results might be a result of alluvial deposition over the years. At 0-13cm depth, the soils were very sticky, very plastic, firm and hard except at 13-27cm depth where the soils were weak, course and loose when dry and moist. The soils were non-sticky, non-plastic and loose in the pedon. This result indicates that the soils were generally deep and strongly structured. James (2010) found soils in the floodplain were shallower and had less distinct sub-surface horizons than the soil at the plain land. A similar trend was observed at BYF P2 (CBN) where the soils were very sticky, very plastic, firm and hard at 0-19cm depth. The soils were very sticky, very plastic, very firm and very hard at 19-34cm depth of the pedon. The presence of many and course roots was observed in all the horizons of the pedon. Similar results were observed by Bengeowgh *et al.* (2001).

Table 3: Some Morphological Characteristics of Soil in the Arable Land Area

Pedon	HD	Depth	Colour (dry)	(Moist)	Mottles	Texture	Structure Grade	Class	Type	Consistency	Inclusions
BYF P2	Ap	0-19	10YR 7/3	10YR 6/4	n	SCL	m,	c,	s.b.k	wss, sp, mf, dh	rmc
	B	19-34	10YR 6/3	10YR 4/1	mcp	C	S,	f,	s.b.k	wvs, vp, mvf, dvh	rmm
	C	34-52	10YR 7/3	10YR 4/2	n	C	S,	f,	s.b.k	wvs, vp, mvf, dvh	rcf
BYF P3	Ap	0-20	10YR 6/3	10YR 4/3	n	LS	m,	m,	s.b.k	wvs,vp, mf, dh	rmm
	E	20-60	10YR 6/6	10YR 5/4	n	S	w,	c,	s.b.k	wns, np, ml, dl	n
	Bt	60-104	7.5YR 6/6	7.5YR 5/6	n	S	w,	c,	s.b.k	wns, np, ml, dl	n
	C	104-132	10YR 8/4	10YR 6/6	n	SC	m,	c,	s.b.k	wss, slp,mf, dh	n
BYF P4	Ap	0-13	10YR 6/4	10YR ¾	n	SCL	S,	m,	s.b.k	wvs, vp, mf, dh	rmm
	AE	13-27	7.5YR 6/2	7.5YR 6/4	n	S	w,	c,	s.b.k	wns, np, ml, dh	rfff
	Bt	27-85	10YR 6/2	10YR 3/2	m	C	S,	f,	s.b.k	wvs, vp, mvf, drh	rff
	C	85-95	10YR 3/1	7.5YR 5/6	mcp	C	S,	f,	s.b.k	wvs, vp, mvf, dvh	rff

KEY: HD: horizon designation, mottles: n=none Texture: S=sand, SL = Sandy loam, SCL = Sandy clay loam, SC = sandy clay. Structure: Grade; w = weak, m = moderate, s = strong. Class; f= fine, m=medium, c=coarse. Type; sbk=subangular blocky. Consistency: wet; ns= non sticky, np = non plastic, ss= slightly sticky, sp= slightly plastic, vs= very sticky, vp= very plastic, moist; l= loose, vf= very friable, f= firm, vf= very firm, Dry; l= loose, s= soft, h=hand, vh= very hard. Inclusion: r=root; Abundance: f = few, c= common, m= many; Size: f= fine, m= medium, c= coarse, n= none.

Result for soil colour is presented in table 3. The study revealed that the soils were very pale brown 10YR (7/3) and light yellowish-brown 10YR (6/4) at 0-19cm depth when dry and moist. This result might be due to material detachment, transportation and the position at the floodplain per water action. Similar colour change for floodplain was reported by Olayel *et al.* (2004). At 19-24cm depth, the soils were pale brown 10YR (6/3) when dried, and dark grey 10YR (4/1) when moist with many coarse and prominent mottles present indicating that soil was seasonally flooded. The soils were very pale brown colour 10YR (7/3) and dark greyish brown 10YR (4/2) at 34-52cm depth when dry and moist.

Pedon BYF P3 showed that the soils were pale brown 10YR (6/3) when dry and brown 10YR (4/3) when moist with no mottles at 0-20cm depth brownish-yellow 10YR (6/6) when dry and yellowish-brown 10YR (5/4) when moist respectively. This result might be due to an increase in organic matter, materials and decomposition by micro-organism at the position's floodplain.

3.3. Some physical properties of the woodland area

Table 4 presents the physical properties of the woodland area. Pedon BYF P1 (Lamurde Bridge) were sandy loamy at 107-140cm depth, and the highest percentage was recorded at 0-37cm depth, sandy loam was recorded at the depth 0-37cm depth of the pedon respectively. The sand content was lowest at 0-37cm depth and had the highest at 37-107cm depth. This varying trend might be due to the soils' irregular nature and how they are cultivated and managed by local farmers in the study area. The soils vary from loamy sandy to sandy loam, and similar results were reported by Ewulo *et al.*(2002).Bulk density of 1.61gm/cm^3 was recorded at 0-37cm depth and lowest (1.53g/cm^3) at 37-107cm depth.

Total porosity at 140-170cm depth was the highest with the value of 41%and lowest at a depth of 0-37cm (39%) respectively. Pedon BYF P5 (water board) were sandy loam in all horizons except the last horizon (120-160) which were loamy sand. The pedon also showed 80.0% sand at 0-25cm depth, indicating high sand deposits. This result might be due to leaching activity of the pedon over time and materials wash down the profile, living coarse sand material at the surface horizon. Total porosity indicated varying trend with depth. This result is supported by the findings of Gwari (2014).

Table 4: Physical Properties for Woodland Area

Pedon	HD	Depth	%Sand	%Silt	%Clay	Textural Class	B.D	%T. Porosity
BYF P1	Ap	0-37	82.2	8.8	9	LS	1.61	39
	A1	37-107	71.2	15.8	13	SL	1.53	42
	A2	107-140	76.2	9.8	14	SL	1.53	42
	E	140-170	71.2	17.8	11	SL	1.55	41
	C	170-200	78.2	5.8	16	SL	1.51	43
BYF P5	Ap	0-25	80	5	15	SL	1.53	42
	A1	25-52	76.2	9.8	14	SL	1.53	42
	A2	52-103	78.2	11.8	10	SL	1.58	40
	E	103-120	79.2	7.8	13	SL	1.55	42
	C	120-160	83.2	4.8	12	LS	1.56	41
BYF P6	Ap	0-25	75.2	7.8	17	SL	1.5	43
	AE	25-60	74.2	16.8	9	SL	1.59	40
	E	60-120	87.2	6.8	6	LS	1.67	37
	Bt1	120-140	61.2	26.8	12	SL	1.52	43
	Bt2	140-170	79.2	8.8	12	SL	1.56	41
	C	170-187	89.2	6.0	4.8	S	1.51	43

Key: HD = Horizon designation, BD = Bulk density

3.4. Some physical properties of soils of the arable land area

Results of some physical properties of arable land are presented in table 5. Results showed that the soils were predominantly loamy sand and sandy in all the pedons. This could be attributed to the soil's sandy nature in the study area resulting from deposition by water. Percentage silt increase with increased horizon depth in pedon BYF P3 from 6.8 (0-20cm) to 30.8 (104-132cm). Sand context varied from 84.2% at 13-27cm depth to 78.2% at 0-13cm depth (BYF P4). Bulk density ranged from 1.59g/cm^{3}to 1.70g/cm^{3}in pedon BYF P2. Similar results were reported by Adriesse (1995). In pedon BYF P3, bulk density of 1.66g/cm^3 was recorded at 104-132cm depth and total porosity at 60-104cm depth with 41% respectively. According to USDA (1996), soil compaction occurs when soil particles are pressed together, reducing the pore space between their field capacity values.

3.5. Some chemical properties of the woodland area

The results of some chemical properties of the woodland area are presented in table 6. Pedon BYF P1 indicated that the soils ranged between 5.80 to 6.10 and were generally rated as moderately acidic soils. Pedon BYF P5 and P6 ranged between 5.20 to 6.50 and were rated moderately acidic to slightly acidic soils, but the soils were neutral at the 0-25cm depth of BYF P6. These results agreed with the report of More (2012). The EC values were recorded ranged between 0.20ds/m to 0.54ds/m at pedon BYF P1, 0.16ds/m to 0.34ds/m at P5 and 0.14ds/m to 0.55ds/m at BYF P6 respectively. Electrical conductivity revealed that the highest value of 0.370ds/m and the lowest value of 0.160ds/m in P5 and similar results were reported by Ojeniyi (2012).

The organic carbon content of the soils in all pedons was rated low (<2%). This result might be connected to intensive cultivation activities in the area over the years. Total nitrogen change in an irregular pattern with increase in profile depth. They were generally rated low (0-0.15%) in all the pedons. The low total nitrogen content might be linked with the low organic carbon in the study area due to the farmers' continuous cultivation activities over some time. The low values observed across the pedons could also be attributed to the continuous cultivation aggravated by the undesirable habit of complete crop residue removal after harvesting. Share *et al.* (2013) reported similar results of low nitrogen of some Fadama soils.

Calcium was rated medium (2-5cmol/kg) across the pedons, and magnesium was also rated medium (0.3-

Table 5: Physical Properties for Arable Land Area

Pedon	HD	Depth	%Sand	%Silt	%Clay	Textural Classes	B.D	%T.Porosity
BYF P2	Ap	0-19	83.2	6.8	10	LS	1.59	40
	B	19-34	80	6	14	SL	1.54	37
	C	34-52	84.2	5.8	10	LS	1.59	40
BYF P3	Ap	0-20	83.2	6.8	10	LS	1.59	40
	E	20-60	85.2	9.8	5	LS	1.7	36
	Bt	60-104	87.2	0.8	12	LS	1.57	41
	C	104-132	64.2	30.8	5	SL	1.66	37
BYF P4	Ap	0-13	78.2	7.8	14	SL	1.53	42
	AE	13-27	84.2	3.8	12	LS	1.57	41
	Bt	27-85	75.2	8.8	16	SL	1.51	43
	C	85-95	80.2	11.8	8	LS	1.62	39

Source: Field Survey, 2019

Table 6: Chemical Properties for Woodland Area

Pedon	HD	Depth (cm)	pH (1:2)	EC (dS/m)	Org.C %	TN %	Ca	Mg	Na	K	H	Al cmol/kg	TEB	TEA	ECEC	PBS
BYF1	Ap	0-37	5.800	0.150	1.077	0.097	5.025	1.075	0.101	0.162	0.416	0.732	6.363	1.148	7.511	84.716
	A1	37-107	5.800	0.490	1.047	0.094	1.478	2.405	0.043	0.111	0.656	1.032	4.037	1.688	5.725	70.515
	A2	107-140	5.567	0.307	1.061	0.096	3.481	0.849	0.077	0.179	0.549	0.899	5.322	1.448	6.770	77.971
	E	140-170	6.100	0.200	1.237	0.111	2.219	1.598	0.193	0.278	0.344	0.642	3.538	0.986	4.524	78.205
	C	170-200	5.900	0.540	1.127	0.102	2.882	1.556	0.043	0.120	0.656	1.032	4.643	1.688	6.331	73.338
			5.830	0.340	1.110	0.100	3.020	1.500	0.100	0.170	0.520	0.870	4.780	1.390	6.170	76.950
BYF5	Ap	0-25	5.900	0.240	1.317	0.119	2.709	0.283	0.058	0.222	0.736	1.132	3.272	1.868	5.140	63.659
	A1	25-52	6.210	0.160	0.938	0.084	5.793	1.132	0.083	0.192	0.736	1.132	7.200	1.868	9.068	79.400
	A2	52-103	6.500	0.330	0.928	0.084	1.985	1.697	0.101	0.546	0.496	0.832	4.330	1.328	5.658	76.531
	E	103-120	6.210	0.340	1.217	0.110	3.399	0.311	0.174	0.171	0.176	0.841	4.055	1.017	5.072	79.945
	C	120-160	5.200	0.370	1.397	0.126	2.956	0.424	0.130	0.179	0.176	0.841	3.690	1.017	4.707	78.389
			6.000	0.290	1.160	0.110	3.370	0.770	0.110	0.260	0.460	0.960	4.510	1.420	5.930	75.590
BYF6	Ap	0-25	7.000	0.550	1.037	0.093	2.709	2.557	0.087	0.120	0.152	0.402	5.473	0.554	6.027	90.808
	AE	25-60	6.310	0.380	1.087	0.098	2.882	1.315	0.087	0.196	0.016	0.841	4.481	0.857	5.338	83.941
	E	60-120	6.500	0.530	1.077	0.097	3.695	1.556	0.248	0.235	0.088	0.322	5.733	0.410	6.143	93.326
	Bt1	120-140	5.800	0.500	1.117	0.101	1.739	0.849	0.087	0.179	0.576	0.932	2.854	1.508	4.362	65.427
	Bt2	140-170	6.500	0.140	1.047	0.094	1.724	2.329	0.550	0.577	0.168	0.352	5.180	0.520	5.700	90.877
	C	170-187	5.800	0.540	0.127	0.102	2.882	1.556	0.043	0.120	0.656	1.032	4.643	1.688	6.331	63.438
			6.320	0.440	0.920	0.100	2.610	1.690	0.180	0.240	0.280	0.650	4.730	0.930	5.650	81.300

Source: Field Survey, 2019

Key: TEB – Total Exchangeable Bases, TEA – Total Exchangeable acidity, ECEC - Effective cation exchange capacity, PBS - Percentage Base Saturation

Table 7: Chemical Properties for Arable Land Area

Pedon	HD	Depth (cm)	pH (1:2)	EC (dS/m)	OC %	TN %	Ca	Mg	Na	K	H cmol/kg	Al	TEB	TEA	ECEC	PBS
BYF2	Ap	0-19	6.000	0.370	1.182	0.106	2.550	1.577	0.118	0.199	0.500	0.837	4.091	1.337	5.428	75.772
	B	19-34	5.600	0.250	0.868	0.078	2.709	1.273	1.321	0.256	0.416	0.732	4.994	1.148	6.142	81.309
	C	34-52	6.700	0.150	1.377	0.124	3.060	0.849	0.058	0.188	0.296	0.582	5.427	0.878	6.305	86.075
			6.100	0.260	1.142	0.103	2.773	1.233	0.499	0.214	0.404	0.717	4.840	1.121	5.960	81.10
BYF3	Ap	0-20	6.150	0.200	1.122	0.101	2.884	1.061	0.689	0.222	0.356	0.657	5.211	1.013	6.224	83.692
	E	20-60	6.700	0.450	1.237	0.111	1.985	0.283	0.101	0.333	0.416	0.732	3.268	1.148	4.416	74.005
	Bt	60-104	6.600	0.170	0.708	0.064	1.478	0.849	0.072	0.521	0.656	1.032	3.910	1.688	5.598	69.846
	C	104-132	6.230	0.400	0.988	0.089	1.970	0.212	0.087	0.137	0.736	1.132	4.033	1.868	5.901	68.343
			6.420	0.305	1.014	0.091	2.080	0.601	0.240	0.303	0.541	0.890	4.110	1.430	5.540	73.971
BYF4	Ap	0-13	5.700	0.180	1.227	0.111	3.328	1.556	0.138	0.128	0.576	0.932	3.877	1.508	5.385	71.997
	AE	13-27	4.400	1.100	1.337	0.120	1.985	1.556	0.101	0.026	0.496	0.832	2.961	1.328	4.289	69.036
	Bt	27-85	6.100	0.200	1.357	0.122	3.695	0.283	0.881	0.812	0.336	0.632	5.599	0.968	6.567	85.260
	C	85-95	5.400	0.493	1.307	0.118	3.003	1.132	0.373	0.322	0.469	0.799	4.146	1.268	5.414	75.431
			5.400	0.493	1.307	0.117	3.003	1.132	0.373	0.322	0.469	0.799	4.150	1.268	5.414	75.431

Source: Field Survey, 2019

1.0cmol/kg) in the area. This result might be due to magnesium bearing materials in the area that found its way into the soil formation and development. Potassium was generally rated as high (>0.3cmol/kg) to medium (0.15-0.3cmol/kg) in the study area. This result indicates high potentials of the soils to support agricultural cultivation. A similar result was reported in the work of Ahmad and Yihenew (2002). Percentage base saturation was rated medium (50-80%) to high (>80%) in all the pedons. This result shows the soils' potentials to support cultivation due to accumulation of exchangeable bases in the study area. A similar result was reported by Atofarati *et al.* (2012) and supported by the findings of Brandy (2012).

3.6. Some chemical properties of soil of the arable land area

The result of some chemical properties of the arable land area is presented in Table 7. The soils in pedon BYF P2 indicated that soil ranged between 6.000-6.700 and slightly acidic at 0-19 and neutral at 34-52 in first and last horizons. Soil pH of pedon BYF P3 ranges from 6.150 – 6.700 and 6.600 – 6.230 for both pedons. A similar result was reported by Adediran (2004) Fageria and Baligar (1998) found that soil pH and base saturation were important soil chemical properties that influence nutrient available and crop growth. The total nitrogen changed in an irregular pattern with increase in profile depth. They were rated low 0-0.15% in the first two horizons, and in second to the last horizon, they were rated medium at (0-0.15-0.2%). The organic carbon content in the soil in the pedon was rated low <2%. EC values recorded were ranged between 0.200ds/m to 0.400ds/m at pedon BYF P3, 0.370ds/m to 0.250ds/m at p2 and 0.180ds/m to 0.200ds/m at p4 respectively. Similar observation made by Ewulo *et al.* (2002).

3.7. Soil fertility capability classification

Table 8 presents the land unit characteristics and quality for soil suitability classification for woodland and arable land area. These characteristics were generated from the pedons' soil properties and matched with the ratings for soil suitability classification. Table 9 presents results for soil suitability classification of maize in the study area. The suitability classification for the woodland area showed overall suitability for maize in pedon BYF1 was S3w (marginally suitable) with limitation in nutrient availability. This might be due to crop nutrient removal as a result of continuous cultivation in the area. Pedon BYF5 was suitable for maize cultivation with no observed limitation. Pedon BYF6 was moderately suitable (S2g); this could be due to the imperfectly drained soils in that location, reducing oxygen availability. However, BYF2 was marginally suitable (S3gw) with limitation in oxygen availability and, loamy sand soils rated marginal for maize cultivation. The depth to the water table is 52cm depth which reduced oxygen availability and not suitable for maize cultivation. Pedon BYF3 had a limitation in soil texture (loamy sand) and marginally suitable for maize cultivation. Pedon BYF4 was not suitable for maize cultivation in the study area. This is because the soils were poorly drained and the pH was 5.40 (strongly acidic), and maize performs best at pH of 6-7 (Slightly acidic to neutral) soils.

Table 10 presents results for soil suitability classification of rice in the study area. The soils in the woodland area were marginally suitable (S3w) in pedon BYF1 and moderately suitable (S2gw) in pedon BYF55 and 6. The soils were moderately well drained, as such might not be suitable for rice cultivation in the area. Furthermore, the soils ranged from loamy sand (BYF1) to sandy loam soils (BYF5 and 6) which is not best for rice cultivation. The soils at the arable land area were imperfectly drained (BYF 2 and 4) except for pedon BYF 3 that was well-drained and was marginally suitable (S3gw) with limitation in oxygen availability and soil texture. This implies that imperfectly drained soils support rice cultivation as against well-drained soils. Furthermore, the limitation in soil texture, that is; loamy sand for BYF2 and 3 were marginally suitable (S3), and sandy loam for pedon BYF 4 was moderately suitable. Therefore, organic matter addition and integrated nutrient management practice will improve the soil texture and structure.

Table 8: Soil Unit Characteristics and Quality for Suitability Classification in the Study Area

Land Quality	**Diagnostic Factor**	**Unit**	**BYF P1**	**BYF P5**	**BYF P6**	**BYF P2**	**BYF P3**	**BYF P4**
Oxygen availability (g)	Drainage	Class	Mod. Well drained	Well drained	Mod. Well drained	Very poorly drained	Well drained	poorly drained
Nutrient availability (a)	Soil reaction	pH	5.83	6.00	6.32	6.10	6.42	5.40
Rooting condition (r)	Depth	Cm	200	160	187	52	132	95
Soil Workability (w)	Texture	Class	LS-SL	SL-LS	SL-LS	LS-SL	LS	SL-LS
Soil Workability (k)	Structure	Class	Strongly Developed	Strongly Developed	Strongly Developed	Mod. Developed	Mod. Developed	Mod. Developed
Erosion Hazard (e)	Slope	%	0-2	0-2	0-2	2-5	2-5	2-5
Nutrient Retention Cap(n)	Base saturation	%	76.95	75.59	81.30	81.10	73.97	75.43

Source: Field Survey, 2019

Land use requirement / Land quality	**Suitability Ratings of Sampling Unit**					
	Woodland Area			Arable land Area		
	BYF 1	BYF 5	BYF 6	BYF 2	BYF 3	BYF 4
Oxygen availability (g)	S2	S1	S2	S3	S1	S3
Nutrient availability (a)	S2	S1	S1	S1	S1	N
Nutrient retention (n)	S1	S1	S1	S1	S1	S1
Rooting condition (r)	S1	S1	S1	S2	S1	S2
Soil wrk (texture) (w)	S3	S1	S1	S3	S3	S1
Soil wrk structure (k)	S1	S1	S1	S2	S2	S2
Erosion hazard (e)	S1	S1	S1	S2	S2	S2
Overall Suitability	S3w	S1	S2g	S3gw	S3wk	N

Source: Field Survey, 2019

Key: wrk=workability, S1=suitable, S2=moderately suitable, S3=marginally suitable

Table 10: Soil Fertility Capability Classification for Rice in the Study Area

Land use requirement / Land quality	Suitability Ratings of Sampling Unit					
	Woodland Area			Arable land Area		
	BYF 1	BYF 5	BYF 6	BYF 2	BYF 3	BYF 4
Oxygen availability (g)	S2	S2	S2	S1	S3	S1
Nutrient availability (a)	S2	S1	S1	S1	S1	S2
Nutrient retention (n)	S1	S1	S1	S1	S1	S1
Rooting condition (r)	S1	S1	S1	S2	S1	S1
Soil wrk (texture) (w)	S3	S2	S2	S3	S3	S2
Soil wrk structure (k)	S1	S1	S1	S2	S2	S2
Erosion hazard (e)	S1	S1	S1	S2	S2	S2
Overall Suitability	S3w	S2gw	S2gw	S3w	S3gw	S2wk

Source: Field Survey, 2019

4.0. Conclusion

This study indicated that soils of the study area had low fertility but recorded high base saturation, which indicates its potentials to support arable crop cultivation with limitation in some physical and chemical soil properties. Soil suitability limitations such as oxygen availability, soil texture and structure were the predominant limitations for maize cultivation in the woodland area while the imperfectly drained soils were the major limitation in the arable land area except for pedon BYF3. The reverse was the case for rice cultivation. Soils of the woodland area were moderately suitability for rice cultivation with limitation in texture and oxygen availability since the soils were well-drained. The arable land area will support rice cultivation due to the poorly drained condition except for BYF 3. Cultural practices like drainage in areas were maize was cultivated, and the addition of organic and inorganic fertilizers will improve the soil condition, improving cohesion and adhesion of soil particles and increasing crop yields for the farmers in the study area. Due to the imperfectly drained condition in some pedon, which suggests water availability, dry season farming could be practice through surface irrigation by pump machine and water management strategies.

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