

LAND CHARACTERISTICS AND SUITABILITY APPRAISAL FOR AGRISILVICULTURE OF FORESTRY RESEARCH INSTITUTE OF NIGERIA (FRIN) IN A HUMID FOREST STATION AT OKWUTA - IBEKU, UMUAHIA SOUTHEASTERN NIGERIA

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ABSTRACT

This study surveyed, characterized and evaluated the land suitability of soils of Forestry Research Institute of Nigeria (FRIN), at the Humid Forest Research Station, Umuahia, covering a land area of about 36.63 ha for agrisilviculture enterprise. A free survey approach method was used for this study. The study area was delineated into mapping units based on land use area and the depth. The soil mapping Unit 1 were represented by pedon A, B, C, D and E and occur on gently undulating landscapes of 8% slope gradient with surface colour ranged from dark brown to strong brown and were moderately acid reaction (pH 5.0-5.8). The soil mapping 2 were represented by pedon F and G which also occurred on a hilly physiographic landscape surface of 172-181m above sea level with less than 12% slope with good internal drainage of shallow depth of less than 100cm with stony or gravelly pedons. The soil had dark brown over reddish yellow to reddish brown with moderately (pH 5.0-5.8). Soil mapping unit 3 were represented by pedon H, I, J, K and L which also occurred on slope of between 6-8 % which had moderate to good internal drainage, moderate deep to deep and gravel free. The soil colour indicated dark brown, to strong brown over brown to brownish yellow possessing a strongly acid (pH. 4.0-4.1) soil reaction. All the soil pedons studied in the study area had kandic soil surface diagnostic horizon. The soil in the study area were grouped under ultisol order with Udic soil moisture regime. The soil were classified as Arenic Kandudults at sub group level. The aggregate suitability evaluation by both limitation and square root method evaluated the soil mapping units 1 and 3 as moderately suitable (S2) and marginally suitable (S3) for agrisilvicultural practices respectively. The soil of mapping unit 2 were evaluated currently unsuitable (N1) for agrisilviculture due to the soil depth limitation and hard pan encounter. The study therefore recommended the use of organic manure to improve the soil structure as well as enhance chemical properties such as CEC and to ameliorate low level of micro-nutrients and fertilization with fertilizer containing micro-nutrients; ploughing and ridging are necessary in soil units 1 and 3 for optimal sustainable agrisilviculture.

Key words: Land Characteristics, Suitability, Evaluation, Agri-silviculture

INTRODUCTION

Agroforestry has immense potential to improve rural livelihood as it offers beneficial alternative to small holder farmers who desire improved farm productivity and income while protecting the environment. Incessant food insecurity has made the lives of farmers increasingly difficult over time. FAO (2004) opined that in order to successfully enhance the livelihood of small holder farmers, conscious and coordinated efforts must be made at all levels to fully utilize the benefits embedded in agroforestry. In order to achieve a high level of environmental sustainability and food security, integrated farming practices that involve

planting trees alongside crops can be quite important. In comparison to conventional farming techniques, Kareemulla *et al.* (2005) stated that agroforestry's sustainability potential has grown due to links between the forest and crop resource industries. Agrisilviculture farming reduces the impact of deforestation and supports the development of an integrated farming system that is more productive and diverse. It is a farming system in which forest trees and arable food crops are planted together at the beginning of a tree plantation establishment (Negi, 2000). Adeoye *et al.* (2014) assert that yields and income

creation were significantly influenced by Agrisilviculture practices.

Land suitability evaluation is a scientific method used to evaluate the degree of fitness of land for a specific purpose (Singua and Swain, 2016). The framework of land evaluation for agroforestry development requires that land be suitable in terms of climate, soil, topography, environmental constraints, disturbance, socio-economic needs and anthropogenic pressure on the available lands (Tandey *et al.*, 2017).

Pardon *et al.* (2018) reported that agrisilviculture contributes significantly to yields and increased productivity of food, feed, fuel and timber. It also helps in climate change mitigation, reducing heat stresses of crops. Agrisilviculture has been linked to significant changes in the physical, chemical and biological characteristics of soils. Enhanced stocks of soil organic carbon is associated with improved water storage capacity and nutrient availability to crops (Takacs *et al.*, 2016).

Kalame *et al.* (2011) stated that intercropping trees with crops secures food and energy resources, lowers the cost of reforestation, increases job prospects and reduces poverty. The declining productivity of soils around the study area, the population pressure and urbanization which has significantly reduced available land for arable farming as well as the need for the establishment of forest belts to mitigate climate change effects has necessitated the present study with the following objectives: To characterize, classify and evaluate the land for

suitability of agrisilvicultural practice, becomes apt.

MATERIALS AND METHODS

Study Area

This study was conducted on soils of Forestry Research Institute of Nigeria (FRIN) at a humid forest research station at Okwuta-Ibeku, Umuahia, South Eastern Nigeria. The forest research station is located at Latitudes 5° 30' 40" and 5° 31' 20" N and longitudes 7° 31' 20" and 7° 31' 50" E (Figure 1). The climate is humid tropical climate, divided into wet and dry seasons. The rainfall is in the range of 2500 – 3500mm. Annual air temperature ranges from 26°C - 28°C. The relative humidity is about 75 - 79% (NIMET, Umudike. Station, 2020). The study area is underlain by one main geological formation, the coastal plain sands comprising largely of poorly consolidated sands (Udosen, 2012).

Field Work / Sampling

Using a hand held Global positioning system, the latitudes, longitudes and altitudes on the base map were cross – checked in the field. Random soil augering was carried out at representative areas to establish the predicted soil mapping units and their boundaries based on soil homogeneity. A total of twelve (12) profile pits were sunk, five (5) in mapping unit 1, two (2) in mapping units 2 and five (5) in mapping unit 3 (Figure 2). Each pit was described according to FAO (2006) guidelines for soil profile description. Soil samples were collected from different genetic horizons for routine analysis.

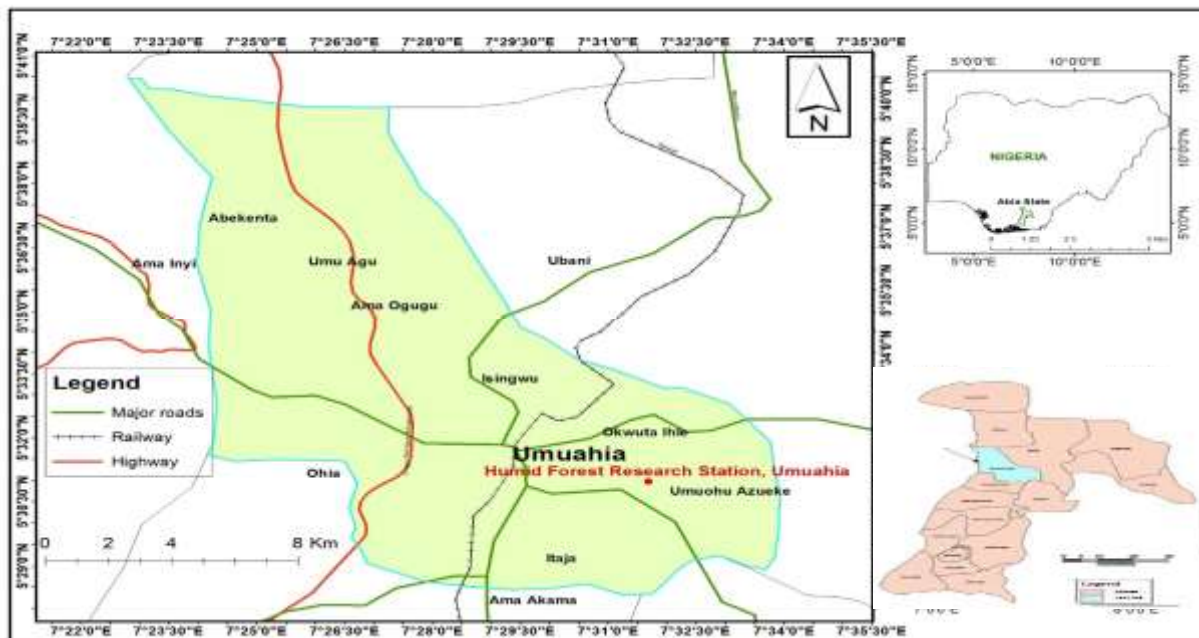


Figure. 1: Map of Nigeria, Abia State, and Umuahia North Local Government Area showing the Study Site at Okwuta-Ibeku.

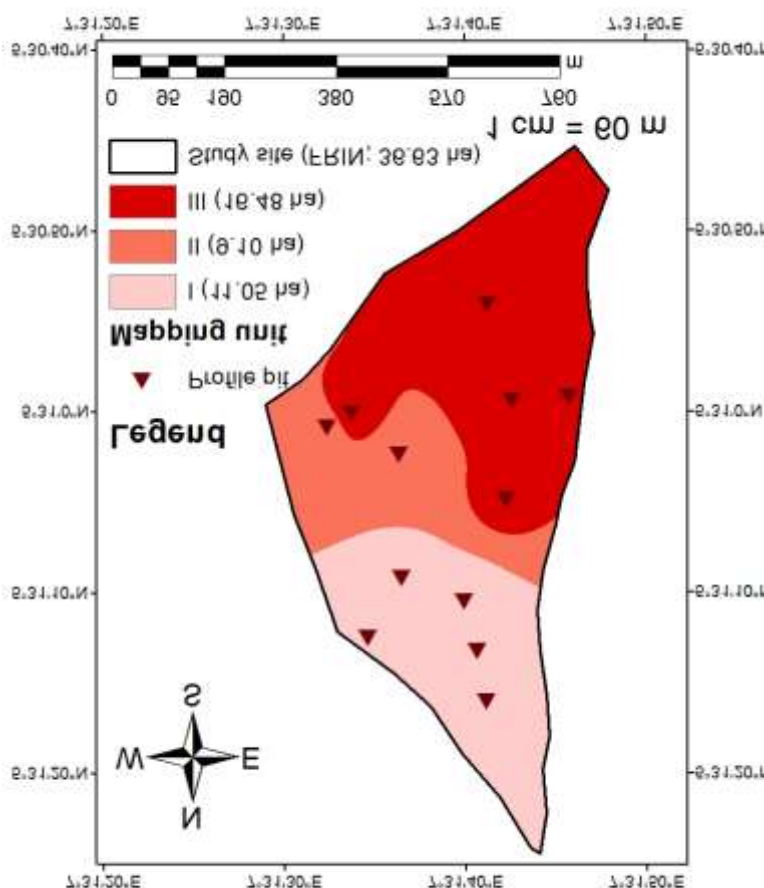


Figure 2: Map of Forestry Research Institute of Nigeria, Umuahia Station with Delineated Mapping Units and Profile Locations

Sample Preparation and Analysis

Soil samples for routine analysis were air dried, crushed gently with a wooden roller and sieved through a 2mm diameter mesh sized sieves and laboratory analysis. Particle size distribution was done by the hydrometer method as outlined in Gee and Or (2002). Bulk density was measured by the cylindrical core method (Anderson and Ingram 1996). Porosity was evaluated using the relationship.

$$\text{Porosity} = (1 - \text{Bd}/\text{Pd}) 100 \% \quad \dots \quad \text{Equation 1.}$$

Where Bd=bulk density, Pd = particle density (2.65 g/cm³).

Soil erodibility index was determined using the relationship.

$$\text{Soil Erodibility index} = \% \text{ sand} + \% \text{ silt}$$

% clay

Equation 2

Soil pH in H₂O was determined by using a pH meter in 1:2.5, soil : water ratio respectively, according to the method of Thomas (1996). Available phosphorus was determined by Bray and Kurtz as modified by Oslen and Sommers (1982). Organic carbon was determined by using Bray and Kurtz (1945) wet oxidation method as outlined by Nelson and Sommer (1996). Total nitrogen was determined by the Kjeldahl method as modified by Bremner (1996). Exchangeable bases were extracted with neutral NH₄OAc solution; exchangeable Ca and Mg were determined by the use of an Atomic Absorption Spectrometer (AAS) while exchangeable K and Na were determined by flame photometry (Grant,1982).Cation exchange capacity (CEC) was measured using ammonium acetate

leaching at pH 7.0 (Rhodes,1982). Base saturation percentage was calculated as follows

$$\text{BS (\%)} = \frac{\text{Total Exchangeable Bases}}{\text{Cation Exchange Capacity}} \times \frac{100}{1}$$

.... Equation 3

Available Micro nutrients (Fe,Zn,Mn and Cu) were extracted with 1N HCl and determined by atomic Absorption Spectrophotometry (AAS) using Association of Analytical chemist (AOAC) 1990 methodology.

Land Suitability Evaluation Procedure

The parametric (square root method) and non parametric (least limitation method) were used to evaluate soils in the study area for agrisilviculture The parametric square Root

method (Khaddir, 1986) was used to calculate the land productivity index using the equation below:

$$\text{PI} = R_{\min} X = \frac{\sqrt{A \times B \times C \times \dots}}{100 \ 100 \ 100}$$

Where:

PI = productivity index (%)
 $R_{\min}$ = factor with minimum rating
 A,B,C etc = ratings of remaining factors

All the factors of the land characteristics were inserted in the square root, except the factor with the least land characteristics limitation among them and PI was calculated. The following percentage ratings according to Riquier *et al*, (1970) were used for these degree of limitations

Percentage ratings %:	100	95	85	60	<40
Degree of limitations:	None	Slight	Moderate	Severe	Very Severe

Based on the resulting index (PI), the soils in the study area were assigned productivity classes as indicated below

Class 1 = (65-100%, excellent)
 Class 2 = (35-64%, good)
 Class 3 = (20-34%, average)
 Class 4 = (8-19%, poor)
 Class 5 = (0-7%, extremely poor)

These productivity classes 1-5 are assumed to correspond to the FAO (2006), Land suitability classes of S1 (High), S2 (Moderate), S3 (Marginal), N1 (Currently not suitable), N2 (Permanently not suitable). This parametric method consists of numerical rating of different limitation levels of land characteristics according to a numerical scale between the maximum and the minimum value.

RESULTS AND DISCUSSION

Morphological Characteristics

The morphological characteristics of soils in the study area are presented in Table 1. The discussions are presented separately for the various mapping units

Soil Mapping Unit 1

The soils of mapping units consist of soils currently under fallow and occurring on gently undulating landscapes distributed on physiographic surfaces 80-100m above sea

level with less than 8% slope. This mapping unit is represented by pedons A, B, C, D and E. Soils of mapping unit I were moderate to somewhat imperfectly drained. The colour of the soils taken at a moist state, indicate that the soils surface colours ranged from Dark brown (10 YR 3/3) to strong brown (7.5 YR 5/6), over reddish brown (5 YR 5/4), Yellowish red (5 YR 5/8) and reddish yellow (7.5 YR 6/6) sub soil colours (Table 1). The dark brown surface colours of this unit is an indication of high organic matter content which might improve its structure and enhance the overall productivity of the soils as also opined by Brady and Weil (2010).

Structurally, the soils of this unit had weak fine crumb or granular surface soils over moderate medium to coarse sub-angular blocky sub soil structures. The soil consistence described at different soil moisture conditions indicate that soils of this mapping unit had loose to soft (dry), very friable to friable (moist) and non-sticky to slightly sticky, non-plastic (wet) epipedons over slightly hard to hard (Dry), firm (moist) and sticky, plastic to very plastic (wet) endopedons (Table 1.1). The sticky, plastic to very plastic wet sub soil consistence is an indication of clay illuviation as evidence in the cutans or clay skins observed

in this pedons in the field. Nsor and Akamigbo (2014), reported similar findings. The pedons of this unit generally clear smooth top soil horizon boundaries over gradual of diffuse wavy sub soils.

Soil Mapping Unit 2

The soils of mapping unit 2 consists of soils currently under natural forest vegetation and natural oil palm occurring on a hilly physiographic landscape surface 172-181m above sea level with less than 12% slope. This mapping unit is represented by pedons F and G. Soils of mapping unit 2 had moderate to good internal drainage, of a shallow depth (less than 100cm) with stony or gravelly pedons.

The colour of soils of this mapping unit taken at moist soil state reveal that the soils had dark brown (7.5 YR 3/2) epipedons over reddish yellow (7.5 YR 6/8) to reddish brown (5 YR 5/4) endopedons (Table 2).

Structurally, the soil had weak fine crumbs top soils over moderate to strong medium sub angular blocky sub soil structures. The consistence of the soils taken at different moisture conditions showed that the soils had soft to loose (dry), friable (moist) and non-sticky, non-plastic (Wet) top soils over slightly hard to hard (dry), firm to very firm (moist) and sticky, slightly plastic to plastic (wet) sub soil (Table 2). The sticky plastic wet sub soil consistence is an indication of illuvial clay deposition suggestive of an ultisol or arfisol soil order (Nsor and Adesemuyi, 2015).

Horizon boundaries in pedons of this soil mapping units were generally clear smooth in epipedon over gradual wavy endopedons. The dark brown top soil is a consequence of decomposed leaf litter piled over the years resulting in floraturbation presumptive of high carbon sequestration (Kalame *et al.*, 2011). At the endopedons of this mapping unit, there was evidence of krotovinas facilitating pedoturbation.

Soil Mapping Unit 3

The soils mapping unit 3 consists of degraded soils currently under old thick afforestation and arable farming occurring on undulating physiographic landscape surface 172-184cm above sea level of between 6-8% slope. This mapping unit is represented by pedons H, I, J, K and L. The soils of mapping unit 3 had moderate to good internal drainage moderately deep to deep and gravel free (145-162cm).

The colour of soils of mapping unit 3 under moist condition indicate a dark brown (10 YR 4/3) to strong brown (7.5 YR 4/6) epipedons over brown (7.5 YR 4/4) to brownish yellow (10 YR 6/6) endopedons (Table 3).

Structurally, the pedons of this unit were characterized by weak fine crumb and granular surface soils over moderate medium to coarse sub angular blocky subsurface soil structures. The consistence of soils of unit 3 at different soil moisture conditions indicate a soft to loose (dry), very friable to friable (moist) and non-sticky, non-plastic epipedons over slightly hard (Dry), firm (moist) and slightly sticky to sticky, plastic to very plastic (wet) endopedons (Table 3). The sticky plastic endopedons consistence is again a strong evidence of sub-soil clay deposition. Horizon boundary characteristics is generally gradual wavy and diffuse wavy.

Table 1: Morphological Characteristics of Soil Mapping Unit 1

					Consistency					
Horizon Designation	Depth	Major colour	Texture	Structure	Dry	Moist	Wet	Roots	Pores	Horizon Boundaries
Pedon A 05°31' 10.53" N 07° 31' 39.96" E 169m above sea level										
Ap	0-20	10 YR 3/3, Db	SL	IF Crumb	l	fr	ns-np	Fine	-	Clear smooth
AB	20-41	7.5 YR 4/4, Sb	SCL	1M Sbk	s	fr	ss-np	Fine	-	Gradual wavy
Bt	44-63	5 YR 5/4, Rb	SCL	2 M Sbk	sh	f	s-p	Very fine	-	-
BC	63-116	5 YR 5/4, Rb	SCL	2 M Sbk	h	f	s-vp	Very fine	-	-
Pedon B 05° 31' 13.25" N 07° 31' 40.69" E 164 m above seas level										
Ap	0-17	10 YR 4/3, Db	LS	IF granular	s	fr	ss-np	Fine	-	Clear smooth
Bt1	17-54	7.5 YR 4/6, Sb	SL	1M Sbk	sh	f	s-p	Fine	-	Gradual wavy
Bt2	54-75	5 YR 5/4, Rb	SCL	2M Sbk	sh	f	s-p	Very fine	-	-
BC	75-145	5 YR 5/8, Yr	SC	2 C Sbk	sh	vf	s-vp	Very fine	-	-
Pedon C 05° 31' 16.039" N 07° 31' 41.200" E 171m above sea level										
Ap	0-17	10 YR 3/3, Db	LS	1F crumb	l	vfr	ns-np	Fine	-	Clear smooth
AB	17-49	7.5 YR 5/6, Sb	SL	2 M Sbk	s	fr	ss-sp	Fine	-	Gradual wavy
BA	49-103	7.5 YR 6/6, Ry	SCL	2 M Sbk	sh	f	s-sp	Very fine	-	-
BC	103-144	7.5 YR 6/6, Ry	SC	2 C Sbk	sh	f	s-p	Very fine	-	-
Pedon D 05° 31' 148" N 07° 31' 36.92" E 170m above sea level										
Ap	0-14	10 YR 3/3, Db	LS	1F granular	s	fr	ns-np	Fine	-	Clear smooth
Bt1	14-34	7.5 YR 5/6, Sb	SL	2 M Sbk	sh	fr	ss-p	Fine	-	Gradual wavy
Bt2	34-88	7.5 YR 6/6, Ry	SCL	2 M Sbk	sh	f	s-p	Very fine	-	-
BC	88-161	7.5 YR 6/6, Ry	SC	2 M Sbk	h	vf	s-vp	Very fine	-	-
Pedon E 05° 31' 12.532" N 07° 31' 34.644" E 168m above sea level										
Ap	0-12	10 YR 4/3, Db	LS	1F granular	l	ffr	ns-np	Fine	-	Clear smooth
Bt1	12-41	7.5 YR 4/4, Sb	SL	2 M Sbk	s	fr	ss-sp	Fine	-	Gradual wavy
Bt2	41-78	7.5 YR 4/4, Sb	SCL	2 M Sbk	sh	f	s-sp	Very fine	-	-
BC	78-148	7.5 YR 6/6, Ry	SC	2 C Sbk	h	vf	s-p	Very fine	-	-

L = loam, SL=Sandy Loam, SCL= Sandy Clay Loam, SC = Sandy Clay, LS = Loamy Sand, l = Loose, s = Soft, sh = Slightly hard, h = Hard, f = Firm, vf = Very firm, fr = Friable, vfr = Very Friable, ns = Non-Sticky, np = Non-plastic, ss = Slightly sticky, s = Sticky, P = Plastic, vp = Very plastic, Sbk = Sub-angular blocky, 1 = Weak, 2 = Moderate, 3 = Strong, F = Fine, M = Medium, C = Coarse

Table 2: Morphological Characteristics of Soil Mapping Unit 2

					Consistency					
Horizon Designation	Depth	Major colour	Texture	Structure	Dry	Moist	Wet	Roots	Pores	Horizon Boundaries
Pedon F 05° 31' 2.401'' N 07° 31' 36.42'' E 175m above sea level										
Ap	0-21	10 YR 3/3, Db	L	1F crumb	s	fr	ns-np	Fine	-	Clear smooth
AB	21-43	10 YR 3/3, Db	SL	2 M Sbk	sh	f	s-p	Fine	-	Gradual wavy
BC	43-92	7.5 YR 6/8, Ry	SiL	3 M Sbk	h	vf	s-p	Very fine	-	-
Pedon G 05° 31' 0.871'' N 07° 31' 32.456'' E 181m above sea level										
Ap	0-20	7.5 YR 3/2, Db	SL	1 F crumb	l	fr	ns-np	Fine	-	Clear smooth
AB	20-45	10 YR ¾, Dyb	SCL	2M Sbk	sh	fr	s-sp	Fine	-	Gradual wavy
BC	45-83	5YR 5/4, Rb	SC	3 M Sbk	sh	f	s-p	Very fine	-	-

L = loam, SL=Sandy Loam, SCL= Sandy Clay Loam, SC = Sandy Clay, LS = Loamy Sand, l = Loose, s = Soft, sh = Slightly hard, h = Hard, f = Firm, vf = Very firm, fr = Friable, vfr = Very Friable, ns = Non-Sticky, np = Non-plastic, ss = Slightly sticky, s = Sticky, p = Plastic, vp = Very plastic, Sbk = Sub-angular blocky, 1 = Weak, 2 = Moderate, 3 = Strong, F = Fine, M = Medium, C = Coarse

Table 3: Morphological Characteristics of Soil Mapping Unit 3

Horizon Designation	Depth	Major colour	Texture	Structure	Consistency						Horizon Boundaries
					Dry	Moist	Wet	Roots	Pores		
Pedon H 05° 31' 0.135'' N 07° 31' 33.785'' E 175m above sea level											
AP	0-19	10 YR ¾, Dyb	LS	1 F crumb	l	vfr	ns-np	Fine	-	Clear smooth	
Bt1	19-42	5 YR 5/4, Rb	SCL	1 M Sbk	s	fr	ns-np	Fine	-	Gradual wavy	
Bt2	42-109	5 YR 5/8, Yb	SCL	2 M Sbk	sh	f	ss-sp	Very fine	-	-	
BC	109-153	5 YR 5/8, Yb	SC	2 M Sbk	sh	f	s-p	-	-	-	
Pedon I 05° 31' 50.15'' N 07° 31' 45.955'' E 172m above sea level											
Ap	0-23	10 YR 4/3, Db	SL	1F granular	l	vfr	ns-np	Fine	-	Clear smooth	
AB	23-40	7.5 YR 4/6, Sb	SCL	1 M Sbk	s	fr	ss-sp	Fine	-	Gradual wavy	
Bt	40-68	10 YR 6/6 By	SCL	2 M Sbk	sh	f	s-p	Very fine	-	-	
BC	68-150	7.5 YR 6/6 By	SC	2 M Sbk	sh	vf	s-vp	-	-	-	
Pedon J 05° 30' 59.193'' N 07° 31' 45.789'' E 172m above sea level											
Ap	0-26	10 YR 3/3, Db	SL	1F granular	s	fr	ns-ns	Fine	-	Clear smooth	
Bt1	26-47	7.5 YR 4/6, Sb	SCL	2 M Sbk	s	fr	s-np	Fine	-	Gradual wavy	
Bt2	47-108	7.5 YR 4/6, Sb	SCL	2 M Sbk	sh	f	s-p	Very fine	-	-	
BC	108-162	7.5 YR 4/4, B	CL	2 C Sbk	h	vf	s-vp	-	-	-	
Pedon K 05° 30' 59.395'' N 07° 31' 42.632'' E 172m above sea level											
Ap	0-26	10 YR 3/3, Db	LS	1 F granular	l	vfr	ns-np	Fine	-	Clear smooth	
Bt1	26-53	7.5 YR 4/6, Sb	SL	2M Sbk	s	fr	ss-sp	Fine	-	Gradual wavy	
Bt2	53-101	7.5 YR 4/6, Sb	SCL	2 M Sbk	sh	f	ss-p	Very fine	-	-	
BC	101-165	7.5 YR 4/4, B	SC	2 M Sbk	h	vf	s-p	-	-	-	
Pedon L 05° 31' 4.922'' N 07° 31' 42.301'' E 184m above sea level											
Ap	0-19	10 YR 3/3, Db	SL	1 F crumb	l	vfr	ns-np	Fine	-	Clear smooth	
AB	19-41	7.5 YR 4/4, B	SCL	1 M Sbk	s	fr	ss-sp	Fine	-	Gradual wavy	
Bt	41-68	10 YR 6/6, By	SCL	2 M Sbk	sh	f	s-p	Very fine	-	-	
BC	68-145	10 YR 6/6, By	SC	2 M Sbk	sh	f	s-p	-	-	-	

SL=Sandy Loam, SCL= Sandy Clay Loam, SC = Sandy Clay, LS = Loamy Sand, l = Loose, s = Soft, sh = Slightly hard, h = Hard, f = Firm, vf = Very firm, fr = Friable, vfr = Very Friable, ns = Non-Sticky, np = Non-plastic, ss = Slightly sticky, S = Sticky, P = Plastic, Vp = Very plastic, Sbk = Sub-angular blocky, 1 = Weak, 2 = Moderate, 3 = Strong, F = Fine, M = Medium, C = Coarse

Physical Properties

Tables 4-6 presents the data of the physical properties of soils in the study area. All the pedons of the various mapping units had high percentage sand content and low percentage clay contents in their surface horizons than their sub-surface horizons. Sand content for mapping unit 1 was in the range (62-90%), mapping unit 2 (29-80%) and mapping unit 3 (45-86 %). Clay content for mapping unit 1 was in the range (7-45%) for mapping unit 2, (16-51%) and mapping unit 3 (12-49%). Silt content was generally low in soil unit 1 and 3 less than 10% except in mapping unit 2 where values of 4-30% were observed (Tables 4-6).

Generally, there was a decrease in percentage sand content with depth, with clay contents increasing with increasing soils depth of all the pedons evaluated. The migration of clay resulted in downward increase in clay content with well-developed argillic horizons. Argillic horizon is a pedogenic diagnostic subsurface condition that shows significantly higher percentage of clay than the overlying soil horizon which is evidence of clay lessivage and illuviation (Bocheirm and Hartemink, 2013). Similar observations had been reported by Essoka and Esu (2011); Nsor (2017). The ratio of silt: clay was less than 1 (<1) in all the profiles, which is an indication that the soils in the study area are

at an advanced stage of weathering and pedogenesis (Bocheirm and Hartemink, 2013).

The textural classes observed showed that in mapping unit 1, loamy sand to sandy loam top soils occurred over sandy clay loam to sand clay sub soil. Soil mapping unit 2 indicate loamy to sandy loam epipedons over sandy clay loam, silty loam to sandy clay endopedons (Tables 4-6). The textural classes observed in soil unit 3 were loamy sand to sandy loam top soils over sandy clay loam, clay loam to sandy clay sub soils. The coarse texture of soils encountered in the study area might be attributed to the coastal plain sand parent materials of the soils (Brady and Weil, 2010).

The range of bulk density recorded in soil mapping unit 1 (1.33 -1.64 g/cm³), soil unit 2 (1.40 -1.69 g/cm³) and soil unit 3 (1.32-1.78 g/cm³) were within the range also observed by Ogban and Ekerette (2001) in coastal plain sands of Eastern Nigeria.

The values of bulk densities in the study area increased down the profile. Similar observation was also reported by Oguike *et al.* (2006). The bulk density values observed across the entire study area were within the values quoted as ideal or optimum at which root restriction conditions are unlikely to occur (Mbagwu *et al.*, 1983).

Table 4: Physical Properties of Soil Mapping Unit 1

Horizon Designation	Depth	Sand	Silt	Clay	Tc	Bd	Silt: Clay
		%	%		Mg/cm ³		
Pedon A 05°31' 10.53'' N 07° 31' 39.96'' E 169m above sea level							
Ap	0-20	80	3	17	SL	1.48	0.18
AB	20-41	72	4	24	SCL		0.17
Bt	44-63	70	2	28	SCL	1.56	0.07
BC	63-116	64	2	36	SCL		0.06
Pedon B 05° 31' 13.25'' N 07° 31' 40.69'' E 164 m above seas level							
Ap	0-17	80	9	11	LS	1.45	0.8
Bt1	17-54	76	6	18	SL		0.3
Bt2	54-75	73	4	33	SCL	1.62	0.1
BC	75-145	58	2	40	SC		0.1
Pedon C 05° 31' 16.039'' N 07° 31' 41.200'' E 171m above sea level							
Ap	0-17	86	7	7	LS	1.43	1.0
AB	17-49	78	5	17	SL		0.3
BA	49-103	73	4	23	SCL	1.49	0.2
BC	103-144	64	2	34	SC		0.1
Pedon D 05° 31' 148'' N 07° 31' 36.92'' E 170m above sea level							
Ap	0-14	90	2	8	LS	1.37	0.3
Bt1	14-34	85	2	13	SL		0.2
Bt2	34-88	76	3	21	SCL	1.67	0.1
BC	88-161	66	2	32	SC		0.1
Pedon E 05° 31' 12.532'' N 07° 31' 34.644'' E 168m above sea level							
Ap	0-12	89	3	7	LS	1.33	0.4
Bt1	12-41	82	7	13	SL		0.5
Bt2	41-78	62	7	31	SCL	1.64	0.2
BC	78-148	50	5	45	SC		0.1

SL =Sandy loam, SCL =Sandy Clay Loam, LS = Loamy Sand, SC = Sandy Clay

Table 5: Physical Properties of Soil Mapping Unit 2

Horizon Designation	Depth	Sand	Silt	Clay	Tc	Bd	Silt: Clay
		%	%		Mg/cm ³		
Pedon F 05° 31' 2.401'' N 07° 31' 36.42'' E 175m above sea level							
Ap	0-21	60	20	20	L	1.40	1.0
AB	21-43	80	4	16	SL		0.3
Bc	43-92	29	20	51	SiL	1.69	0.4
Pedon G 05° 31' 0.871'' N 07° 31' 32.456'' E 181m above sea level							
Ap	0-20	78	5	17	SL	1.44	0.3
AB	20-45	70	4	26	SCL		0.2
BC	45-83	64	2	34	SC	1.65	0.1

SL =Sandy loam, SCL =Sandy Clay Loam, LS = Loamy Sand, SC = Sandy Clay

Table 6: Physical Properties of Soil Mapping Unit 3

Horizon Designation	Depth	Sand	Silt	Clay	Tc	Bd	Silt: Clay
		%	%		Mg/cm ³		
Pedon H 05° 31' 0.135'' N 07° 31' 33.785'' E 175m above sea level							
Ap	0-9	86	2	12	LS	1.32	0.2
Bt1	19-42	76	2	22	SCL		0.1
Bt2	42-109	73	2	25	SCL	1.77	0.1
BC	109-153	60	3	37	SC		0.1
Pedon I 05° 31' 50.15'' N 07° 31' 45.955'' E 172m above sea level							
Ap	0-23	74	7	19	SL	1.41	0.3
AB	23-40	68	4	28	SCL		0.1
Bt	40-68	54	4	42	SCL	1.78	0.1
BC	68-150	50	10	40	SC		0.3
Pedon J 05° 30' 59.193'' N 07° 31' 45.789'' E 172m above sea level							
Ap	0-26	80	4	16	SL	1.43	0.3
Bt1	26-47	70	2	28	SCL		0.1
Bt2	47-108	50	5	45	SCL	1.75	0.1
BC	108-162	45	6	49	CL		0.1
Pedon K 05° 30' 59.395'' N 07° 31' 42.632'' E 172m above sea level							
Ap	0-26	85	3	12	LS	1.38	0.31
Bt1	26-53	81	2	17	SL		0.1
Bt2	53-101	76	1	23	SCL	1.71	0.1
BC	101-165	60	2	38	SC		0.1
Pedon L 05° 31' 4.922'' N 07° 31' 42.301'' E 184m above sea level							
Ap	0-19	82	2	16	SL	1.36	0.1
AB	19-41	70	2	28	SCL		0.1
Bt	41-68	64	2	34	SCL	1.64	0.1
BC	68-145	52	1	47	SC		0.1

SL =Sandy loam, SCL =Sandy Clay Loam, LS = Loamy Sand, SC = Sandy Clay

Chemical Characteristics

Tables 7-9 presents the data on chemical characteristics of soils in the study area. The result indicate that the soils of mapping unit 1 and 2 were moderately acidic in reaction (pH 5.0-5.8) whereas soils of mapping unit 3 were strongly acid (pH 4.1-4.0). The moderately to strongly acid conditions might be attributed to the nature of acidic coastal plain sand parent materials, erosion, high annual rainfall and high leaching rate. Ogban and Ekerette (2001), and Chikezie *et al.* (2010) reported similar findings in coastal plain sand soils of southeastern Nigeria. Organic carbon was rated medium to high (6.1 -17.2kg/kg) for mapping unit 1 and 2, but low to medium (0.2-8.0 g/kg) in mapping unit 3. Organic carbon decreased down the profile in all the pedons evaluated. The higher content of organic matter at the top soils could be due to increased leaf litter droppings on top soils than its pedoturbation into sub soils. Again moderate to high contents of organic carbon in mapping unit 1 and 2 might be due to crop residue incorporations and long-term fallows whereas its low to medium level in soil unit 3 is the direct consequence of continuous cropping. It was also observed that bush burning was the major method of weed control in soil unit 3 and this most likely would have contributed to the lowering of the organic carbon content (Nuga *et al.*, 2008). Total nitrogen content was low to medium (0.6-1.9g/kg) in mapping unit 1 and 2 but low (0.1-1.1 g/kg) in soil mapping unit 3. The low nitrogen content in soil units 3 may be due to microbial degradation by burning of nitrogen mineralizing organisms (Duke, 1983). Content or amounts of total nitrogen also reflects the contents of organic carbon (Enwezor *et al.*, 1981).

Total nitrogen contents were low to medium (0.7 – 1.6 g/kg) in mapping units 1 and 2, and very low to low (0.1-0.8 g/kg) in mapping unit 3, with the tendency to decrease with soil depth (Tables 7-9). Light textured soils are naturally poorly endowed with native nitrogen (Wild, 1993) and this is particularly so with the “acid sands” of southeastern Nigeria with inherent low levels of organic matter (Enwezor *et al.*, 1990), high levels of leaching consequent upon high rainfall and high level of relative humidity. The low to medium of nitrogen encountered in the study area may also had

resulted from volatilization especially under high temperature regimes, denitrification processes and plant uptake without commensurate replenishment, conditions which are prevalent in the study area.

In the study area, available phosphorus was low to medium (1.4 – 12.1 mg/kg) in units 1 and 2, but low (0.6 -9.1 mg/kg) in soil unit 3. The low to medium contents of available phosphorus might be due to the high phosphorus fixing capacity of the coastal plain sandy soils (Udo, 1981). This observation of low to medium phosphorus values agrees with the findings of Eshett (1987); Enwezor *et al.* (1990); Ballard and Fiskel (1974), who remarked that most Nigerian soils have low phosphate reserves. The values of available phosphorus observed in all the pedons were lower than the upper critical limit of 20 mg/kg stipulated for the “acid sand”: (coastal plain sands) of southeastern Nigeria (FPDD, 1989), suggesting that applied phosphorus is required for optimal performance of arable and tree crops.

The exchangeable bases were generally low to medium in concentrations decreasing irregularly with increasing depth of profiles (Table 3) but considerably dominating the soils exchange matrix. Exchangeable calcium content was low to medium (1.44 -3.05 cmol/kg) in soil unit 1 and 2 but low (1.25-1.80 cmol/kg) in soil unit 3. Magnesium was medium to high (0.25-1.80 cmol/kg), but low (0.20-0.31 cmol/kg) in unit 3. Exchangeable potassium was medium (0.12 -0.50 cmol/kg) for soil units 1 and 2, and low (0.05 -0.14 cmol/kg) in soil unit 3. The values of calcium and magnesium at present are far below the values, 5.0 meq ca/100g soil (5.0 cmol/kg) and 1.0 meq/100g soil (1.0 cmol/kg) proposed as critical limits respectively for exchangeable Ca and Mg (Taylor and Pohlen, 1970) in similar tropical soils in New Zealand. In Nigeria, Lombin and Fayemi (1975) suggested that values below 3.0 cmol/kg and 0.3 cmol/kg for calcium and magnesium respectively were useful indications of potentials calcium and magnesium deficiencies. Values of Ca and Mg in the study area were low to medium and may be needed in medium to high levels of optimal productivity. The ranges in values of exchangeable potassium were comparable with the 0.04 -0.16 cmol/kg reported by Amalu (1997) for similar acid sands grown to rubber

trees and Iren and Amalu (2012) for similar soils supporting oil palm trees, all in the same agro-ecology and parent material. However when compared with the upper critical limit of 0.31 cmol/kg exchangeable K earlier established (Unamba-Opara, 1985), than the soils in the study area are equally potassium deficient. These soils will likely respond to potassium fertilization. For enhanced productivity of the soils in these acid sand study area, at present would require modest quantities of calcium and magnesium in any liming programme as well as high quantities of good quality phosphate and potassium fertilizers and compost manuring. These soils are moderately sloppy (Table 1), sandy (Table 2) and subject to intense rainfall amounts, any liming, fertilization or manuring regime will only be effective, if it is applied in split doses, but more frequently to avoid severe losses due to surface run-off and leaching.

The cation exchange capacity (CEC) values in the study area were medium to high (6.0-16.4 cmol/kg) for soil mapping units 1 and 2, but low (5.2 -8.2 cmol/kg) in mapping unit 3. The low to medium CEC values encountered are indicative of the low to moderate nutrient reserves of these soils arising from their low to medium organic matter content (Table 3) and complicated by their coarse textures (Table 3). The base saturation percentage of the soils in all the pedons evaluated were all less than 35 % by NH_4OAc method, suggestive of an ultisol soil order. This low base saturation percentages, implies that these soils would require special

management strategies for enhance productivity agrisilvicultural practices intended in the study area.

Data on available micro nutrient contents (iron, Zinc, manganese and copper) in the study area are shown on Table 3. Iron was low to adequate (0.15-3.15 mg/kg) in the entire study area. This might be due to the coastal plain sands parent material. Chude *et al.* (1993) had previously stated that Nigerian soils derived from basic rocks such as basalt and amphiboles have higher contents of micro-nutrients than those derived from acid granites sandstones and coastal plain sands. Zinc was low to adequate (0.85 -2.35 mg/kg). Zinc specifically plays a role in protein synthesis in the formation of some growth hormones and in the reproduction processes of certain plants (Brady and Weil, 2008). Hence its low to adequate level is an advantage to the lands intended use. Manganese, particularly essential for certain nitrogen transformations in plants was low (< 5.0 mg/kg) in the entire study area. Available copper was low to adequate (0.18- 2.05 mg/kg). The low to adequate levels of Mn and Cu are attributable to their acid coastal plain sand origin. These low levels of micronutrients must be ameliorated by organic manuring according to the recommendations of Stevenson and Ardakani (1972), and fertilization with fertilizer containing these micronutrients. Micronutrient deficiencies causes serious decrease in crop yields and under extreme condition total crop failure (Cotteinie *et al.*, 1981).

Table 7: Chemical Properties of Soil Mapping Unit 1

Horizon Designation	Depth	pH (H ₂ O)	Oc ←	N g/kg	OM →	P Mg/k g	EA ←	Ca	Mg Cmol/kg	Na	K →	CEC	BS (%)	Zn ←	Mn g/kg	Fe →	Cu
Pedon A 05°31' 10.53" N 07° 31' 39.96" E 169m above sea level																	
Ap	0-20	5.46	15.6	1.4	26.9	12.1	1.22	2.46	0.33	0.50	0.22	11.6	30.3	1.40	2.41	2.09	0.48
AB	20-41	5.50	10.6	1.1	18.3	10.3	1.42	2.29	0.30	0.20	0.20	10.4	28.8	2.15	1.17	3.15	0.34
Bt	44-63	5.61	5.8	0.6	10.0	6.1	1.34	1.66	0.41	0.12	0.30	10.1	24.6	1.63	0.95	1.58	0.55
BC	63-116	5.51	3.1	0.7	5.3	4.0	0.90	2.33	0.35	0.15	0.25	9.2	33.5	1.17	0.18	1.24	0.48
Pedon B 05° 31' 13.25" N 07° 31' 40.69" E 164 m above seas level																	
Ap	0-17	5.58	16.2	1.6	27.9	10.7	1.75	2.32	0.65	0.45	0.12	12.1	29.3	2.20	3.10	2.40	0.57
Bt1	17-54	5.56	12.3	1.0	21.2	6.6	1.83	1.81	0.60	0.30	0.10	8.6	32.7	1.60	1.20	1.05	0.27
Bt2	54-75	5.61	6.2	0.6	10.7	6.1	1.70	2.21	0.55	0.27	0.15	9.3	34.2	1.40	1.10	1.11	0.65
BC	75-145	5.55	2.6	0.7	4.5	2.1	1.67	2.12	0.40	0.13	0.20	8.6	33.1	0.95	0.75	0.85	0.60
Pedon C 05° 31' 16.039" N 07° 31' 41.200" E 171m above sea level																	
Ap	0-17	5.62	13.1	1.7	22.6	9.6	1.36	2.54	1.00	0.15	0.20	13.5	28.9	1.20	2.58	3.10	1.62
AB	17-49	5.58	12.1	1.5	20.9	7.2	1.20	2.11	1.85	0.10	0.16	11.4	28.2	1.70	3.40	1.35	1.22
BA	49-103	5.48	8.3	0.9	14.3	2.2	1.20	2.60	0.60	0.15	0.25	10.6	34.0	1.05	1.10	1.44	0.25
BC	103-144	5.64	3.0	0.6	5.2	1.4	1.15	1.44	0.80	0.15	0.24	10.1	26.0	0.85	1.20	1.60	0.52
Pedon D 05° 31' 148" N 07° 31' 36.92" E 170m above sea level																	
Ap	0-14	5.61	12.6	1.1	21.7	10.2	1.30	2.72	1.10	0.20	0.14	14.3	29.1	2.10	3.00	2.20	0.67
Bt1	14-34	5.58	11.1	1.0	19.1	6.1	1.70	1.81	0.70	0.25	0.10	8.8	32.5	1.50	1.10	1.05	0.25
Bt2	34-88	5.56	6.6	0.6	11.4	3.3	1.25	2.35	0.80	0.10	0.20	11.2	30.8	1.10	0.20	1.20	0.40
BC	88-161	5.64	3.3	0.8	5.7	1.8	0.95	2.60	0.50	0.10	0.15	10.6	31.6	1.22	1.00	1.32	0.32
Pedon E 05° 31' 12.532" N 07° 31' 34.644" E 168m above sea level																	
Ap	0-12	5.60	12.1	1.2	20.9	6.7	1.35	2.40	1.30	0.15	0.35	14.2	29.6	2.30	2.90	2.42	0.77
Bt1	12-41	5.40	8.6	1.1	14.8	3.1	1.45	1.70	1.05	0.20	0.30	11.5	28.3	1.70	1.30	1.12	0.37
Bt2	41-78	5.52	3.2	0.7	5.5	2.2	1.35	2.32	1.45	0.10	0.40	13.2	32.3	1.50	1.21	1.22	0.55
BC	78-148	5.50	2.4	0.7	4.1	2.4	1.40	2.30	1.65	0.10	0.50	14.1	32.3	0.90	0.70	0.80	0.50

Where: OM = Organic matter, C = Organic carbon, EA = Exchangeable acidity, ECEC = Effective Cation Exchange Capacity, BS = Base Saturation

Table 8: Chemical Properties of Soil Mapping Unit 2

Horizon Designation	Depth	pH (H ₂ O)	Oc ←	N g/kg	OM →	P Mg/kg	EA ←	Ca	Mg Cmol/kg	Na	K →	CEC	BS (%)	Zn ←	Mn g/kg	Fe →	Cu
Pedon F 05° 31' 2.401'' N 07° 31' 36.42'' E 175m above sea level																	
Ap	0-21	5.70	17.1	1.6	29.5	11.3	1.45	3.05	1.80	0.30	0.45	16.4	34.1	1.40	2.40	2.30	0.38
AB	21-43	5.50	12.5	1.2	21.6	10.5	1.30	2.60	1.50	0.20	0.40	14.6	32.2	1.10	0.24	1.24	0.40
Bc	43-120	5.80	6.0	1.0	10.3	10.1	1.15	3.00	1.65	0.10	0.35	15.1	33.8	1.20	1.01	1.40	0.20
Pedon G 05° 31' 0.871'' N 07° 31' 32.456'' E 181m above sea level																	
Ap	0-20	5.30	17.2	1.9	12.4	4.4	2.25	1.50	0.23	0.10	0.10	6.5	30.0	1.40	2.30	2.10	0.80
AB	20-45	5.25	17.0	1.4	12.1	1.6	2.60	1.60	0.25	0.05	0.19	6.1	31.0	1.50	3.25	3.15	0.40
BC	45-83	5.00	14.4	0.9	7.6	0.6	2.41	1.42	0.28	0.05	0.19	6.0	31.0	1.15	2.15	2.15	0.50

Where: OM = Organic matter, C = Organic carbon, EA = Exchangeable acidity, ECEC = Effective Cation Exchange Capacity, BS = Base Saturation

Table 9: Chemical Properties of Soil Mapping Unit 3

Horizon Designation	Depth	pH (H ₂ O)	Oc	N g/kg	OM	P Mg/kg	EA	Ca	Mg	Na	K	CEC	BS (%)	Zn	Mn g/kg	Fe	Cu
Pedon H 05° 31' 0.135" N 07° 31' 33.785" E 175m above sea level																	
Ap	0-19	4.30	8.0	0.6	13.8	6.4	2.10	1.62	0.24	0.10	0.12	7.5	27.7	1.50	2.30	2.35	0.75
Bt1	19-42	4.20	6.1	0.5	10.5	6.1	2.25	1.30	0.20	0.10	0.09	7.1	24.9	1.60	1.44	1.05	0.45
Bt2	42-109	4.22	4.7	0.2	8.1	4.2	2.20	1.25	0.30	0.05	0.10	7.2	23.6	1.33	1.30	2.05	0.39
BC	109-153	4.23	2.20	0.2	3.8	4.1	2.35	1.40	0.26	0.05	0.05	5.5	22.0	1.90	1.60	1.11	0.18
Pedon I 05° 31' 50.15" N 07° 31' 45.955" E 172m above sea level																	
Ap	0-23	4.20	1.6	0.8	2.8	8.4	2.10	1.62	0.26	0.15	0.14	7.6	28.6	2.30	1.40	2.10	0.60
AB	23-40	4.06	0.6	0.6	1.0	8.0	2.15	1.30	0.15	0.10	0.16	6.6	24.4	2.35	1.14	1.12	0.35
Bt	40-68	4.12	1.5	0.1	2.6	4.3	2.36	1.45	0.22	0.10	0.10	6.1	30.7	1.60	0.90	1.10	0.65
BC	68-150	4.16	0.3	0.2	0.5	4.6	2.30	1.35	0.20	0.05	0.10	7.2	23.6	1.33	0.80	0.70	0.30
Pedon J 05° 30' 59.193" N 07° 31' 45.789" E 172m above sea level																	
Ap	0-26	4.24	1.0	0.4	3.1	9.1	2.55	1.40	0.16	0.20	0.10	6.0	31.0	1.45	1.25	2.15	0.32
Bt1	26-47	4.16	1.1	0.3	1.9	7.3	2.40	0.09	0.10	0.15	0.06	5.2	26.9	1.58	1.20	1.60	0.22
Bt2	47-108	4.21	0.4	0.1	0.7	6.6	2.50	1.22	0.25	0.15	0.05	5.8	28.8	1.09	0.85	1.55	0.10
BC	108-162	4.28	0.2	0.1	0.3	4.8	2.30	1.20	0.20	0.10	0.10	5.6	28.6	1.15	0.55	0.50	0.10
Pedon K 05° 30' 59.395" N 07° 31' 42.632" E 172m above sea level																	
Ap	0-26	4.27	1.3	1.0	2.2	6.5	2.40	1.80	0.23	0.25	0.12	8.2	29.3	2.20	1.15	2.15	0.33
Bt1	26-53	4.06	1.1	1.0	1.9	3.3	2.35	1.25	0.21	0.10	0.08	7.0	23.4	2.15	1.25	1.20	0.20
Bt2	53-101	4.30	0.8	0.6	1.4	2.4	2.30	1.30	0.26	0.06	0.11	5.5	31.5	1.90	1.95	1.15	0.16
BC	101-165	4.32	0.6	0.7	1.0	3.0	2.31	1.30	0.15	0.06	0.10	5.6	28.8	1.75	0.80	0.90	0.18
Pedon L 05° 31' 4.922" N 07° 31' 42.301" E 184m above sea level																	
Ap	0-19	4.50	1.6	0.8	2.8	6.9	2.45	1.56	0.20	0.20	0.10	7.4	27.8	2.25	1.80	3.10	2.05
AB	19-41	4.60	1.5	0.5	2.6	6.5	2.40	1.21	0.18	0.10	0.06	7.0	22.1	1.50	1.56	2.35	1.24
Bt	41-68	4.58	0.9	0.2	1.6	2.9	2.35	1.30	0.22	0.10	0.06	7.1	23.7	2.05	1.20	1.50	0.80
BC	68-145	4.51	0.3	0.4	0.5	3.1	2.45	1.25	0.31	0.10	0.5	5.20	32.9	1.10	1.12	1.65	1.30

Where: OM = Organic matter, C = Organic carbon, EA = Exchangeable acidity, ECEC = Effective Cation Exchange Capacity, BS = Base Saturation

Classification of Soils in the Study Area

All the soil pedons studied in the study area had Kandic soil surface diagnostic horizons and base saturation by ammonium acetate method of less than 35%. Consequently, the soils in the study area can be grouped under the Ultisol order (Soil Survey Staff, 2010). The soils in the study area occur under an udic soil moisture regime, hence at the sub-order level of the USDA soil taxonomy, they are classified Udults. All the pedons had a vertically continuous subsurface horizon that underlies coarser textured surface horizons. The minimum thickness of their surface horizons was 20-25cm with not densic, lithic, paralithic or petroferic contact within 50cm of the mineral surface soil. All the soil pedons have apparent CEC by 1N NH_4OAC at pH 7.0 of less than 16 cmol/kg. The entire profiles had a regular decrease in organic carbon content with increasing profile depth. These soil characteristics met the conditions for Kandic sub soil diagnostic horizons and this qualified the soils in the study area as Kandiodults at the great group level of soil classification. At the sub group levels, the soils of the study area were classified Arenic Kandiodults due to their sandy or sandy skeletal particle size class texture throughout a layer extending from the mineral soil surface to the top of their Kandic horizon. The world Reference Base (WRB) equivalent of Arenic Kandiodults is Arenic Acrisols.

Land Suitability Evaluation of Soils in the Study Area

A summary of land characteristics or qualities of the study area is presented in Tables 1-9. The assessment ratings resulting from matching of the land qualities and the requirements of the test crops (vegetables, cassava, maize, yam and forestry as an aggregate for all (Agrisilviculture) in Table 10. and 11.

Suitability Evaluation for Agrisilviculture

The climatic elements (rainfall and temperature) in the study area were scored 95 % (S1) for all soil mapping units (Table 11.) in

terms of drainage all the soil units were also scored 95 %, since the soils are all well-drained and thus highly suitable (S1) for agrisilvicultural practice. The soils in the study area were rated moderately suitable (S2) for slope, since slope in all the soil mapping units were between 8-12 % (Fig. 2). The soils in all the units examined possessed a uniform texture of loamy sand and sandy top soils over sandy clay loam subsoil, hence they were rated moderately suitable (S2) and scored 85 %. In terms of soil depth, soils of mapping unit 1 and 3 were rated highly suitable (S1) since their soil depths exceeded 100 cm whereas soils of unit 2 were rated not suitable (N1), due to shallow effective rooting depths of less than 100cm. Sub soils in mapping units were inundated with stones and cobbles that will hinder arable cropping. Bulk density for all the soil units were in the range of 1.22-1.65 g/cm^3 and would not likely impeded not penetration and development (Asadu *et al.*, 1990), hence were rated moderately suitable (S2). Organic carbon content was highly suitable (S1) in soil unit 1 and 2 and moderately (S2) in soil unit 3 for agrisilvicultural practices in the study area. Available phosphorus was moderately suitable (S2) across the entire study area (Table 5). Soil pH was moderately suitable for unit 1 and 2 but marginal for unit 3 (Table 11). CEC was also moderate for unit 1 and 2 but marginal for soil unit 3. Exchangeable K, a nutrient elements in high demand by most arable crops (cassava, yam etc) was moderate (S2) in the entire study area. Most cationic micronutrient elements (Mn, Zn, Cu and Fe) were moderately suitable (S2) for all the soil units investigated.

Aggregate suitability evaluation by both limitation and square root methods evaluated the soils of mapping unit 1 and 3 as moderately suitable (S2) and marginally suitable (S3) for agrisilvicultural practices respectively. The soils of unit 2 were evaluated unsuitable (N1) due to soil depth limitation and encountered of hard pan (Table 11).

Table 10: Land Quality Rating for Agrisilviculture

Land quality	Unit	S1	S2	S3	N1	N2
Characteristics		95%	85%	60%	40%	20%
Climate (c)						
Temperature	°C	32-18	22-16	16-14	<14	Any
Rainfall	mm	2500-2000	1500-2000	1500-1100	1100-500	<500
Wetness (w)						
Soil Drainage		WD	Imperfectly - Drained	Poorly Drained	PD-VPD	-VPD
Topography (t)						
Slope	%	0-4	4-8	8-16	16-25	>25
Soil Physical Characteristics						
Soil texture		SiL, L, CL, SCL	SiCL, LS, SL	C	S	CS
Soil Depth	Cm	>100	75-100	50-75	<50	<50
BD	g/cm ³	<1.2	1.2-1.7	1.7-1.9	>1.9	>2.0
Fertility (f)						
Organic C	g/kg	12-7	7-5	5-2	<2	<2
Avail P.	Mg/kg	>25	6-25	<6	Any	Any
pH		5.5-7.5	5.0-5.5	4.0-5.0	> 4, <7.5	Any
CEC	Cmol/kg	24-16	16-10	>5	<5	<5
BS	%	>3.5	35-20	20-15	<15	<10
TN	g/kg	>1.5	0.8-1.5	0.4-0.8	<0.4	<0.1
Exch. K.	Cmol/kg	>0.5	0.3-0.5	0.1-0.3	<0.1	<0.1
Mn	Mg/kg	>20	15-20	12-15	<12	<4
Zn	Mg/kg	>15	12-15	8-12	<8	<4
Cu	Mg/kg	>10	6-10	4-6	<4	<1

Source: Oluwatosin and Ojoatere (2001); Sys *et al.* (1991).

WD = Well drained, Pd = Poorly drained, VPD = Very poorly drained, Si = Silty, L = Loamy, Cl = Clay Loan, C = Clay

Table 11: Suitability Class Scores of the Study Area for Agrisilviculture

Land qualities/Characteristics	Soil Unit1	Soil Unit 2	Soil Unit 3
Climate (c)			
Annual Rainfall	95 (S1)	95 (S1)	95 (S1)
Average Temperature	95 (S1)	95 (S1)	95 (S1)
Wetness (w)			
Drainage	95 (S1)	95 (S1)	95 (S1)
Slope	85 (S2)	85 (S2)	85 (S2)
Soil Physical Characteristics			
Soil Texture (Structure)	85 (S2)	85 (S2)	85 (S2)
Soil Depth	95 (S1)	40 (N1)	95 (S1)
Bulk Density	85 (S2)	85 (S2)	85 (S2)
Fertility (f)			
Org. C.	95 (S1)	95 (S1)	85 (S2)
Avail P	85 (S2)	85 (S2)	85 (S2)
pH	85 (S2)	85 (S2)	60 (S3)
CEC	85 (S2)	85 (S2)	60 (S3)
BS	85 (S2)	85 (S2)	85 (S2)
TN	85 (S2)	85 (S2)	85 (S2)
Exch. k.	85 (S2)	85 (S2)	85 (S2)
Mn	85 (S2)	85 (S2)	85 (S2)
Zn	85 (S2)	85 (S2)	85 (S2)
Cu	85 (S2)	85 (S2)	85 (S2)
Fe	85 (S2)	85 (S2)	85 (S2)
Aggregate Suitability by Limitation	S2	N1	S3
Productivity Index by Square Root	35.17%	12.55%	20.4%
Rating by Square root	S2	N1	S3

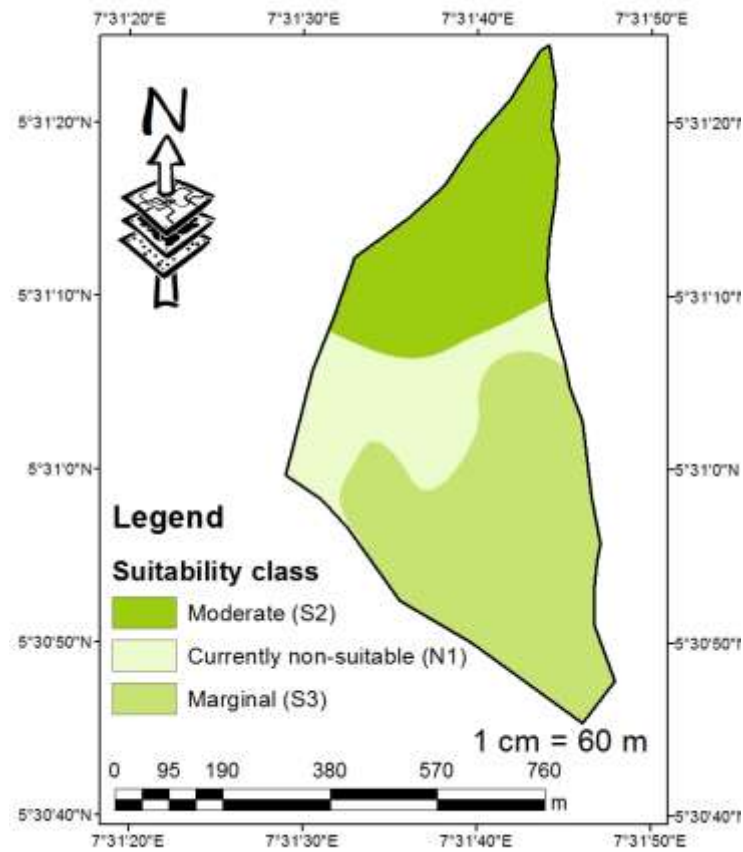


Fig. 3: Suitability Map for Agrisilviculture of the Study Area

SUMMARY AND CONCLUSION

Land characteristics such as rainfall, temperature of the studied sites were all favorable for agrisilvicultural practice. Cation exchange capacity (CEC), an index of the potential of the soil to retain and release plant nutrients was moderately adequate in mapping unit 1 and 2 but low in unit 3. The low to moderate organic carbon in the entire study area can be improved through adoption of management practices that may encourage returns of crop residues into the soil such as planting and incorporation of legumes and application of farm yard manure. The near flat to undulating gentle topography of mapping unit 1 and 2 favoured the moderately well drained soil condition that is required for agrisilviculture practice. The major factor which limited the suitability of soil unit 2 for agrisilviculture was sub soil stoniness and shallow rooting zone. Ploughing and ridging are necessary in soil units 1 and 3 for optimal sustainable agrisilviculture. In the alternative, soil mapping unit 2 can be used for pasture and ranching.

RECOMMENDATIONS

Based on the result of this research, the following recommendations were made:

1. Organic manure is needed to improve the soil structure as well as enhance chemical properties such as CEC and to ameliorate moderate to high level of micro-nutrients.
2. Fertilization with fertilizers containing micro-nutrients.
3. There is need for special agronomic management strategies and good land management practices to enhance productivity of agrisilvicultural practices intended in the study area.

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