ISSN: 1394-7990
Malaysian Journal of Soil Science Vol. 17: 17-37 (2013) Malaysian Society of Soil Science

Agricultural Potential of the Beach Ridge Soils of the Niger Delta, Nigeria

Udoh, B.T.*[1], I. E. Esu[2], T. O. Ibia[1], E. U. Onweremadu[3] and S. E. Unyienyin[1]

[1] Department of Soil Science, and Land Resources Management University of Uyo, Uyo, Nigeria
[2] Department of Soil Science, University of Calabar, Calabar, Nigeria
[3] Department of Soil Science and Technology, Federal University of Technology, Owerri, Nigeria

ABSTRACT

This study aimed to characterize, classify and evaluate the agricultural potentials of soils formed from the beach ridge sands parent material in the Niger Delta area of Akwa Ibom State, Nigeria. Three toposequences were used as study sites. Along with each toposequence, three profile pits were studied – one at the crest, middle slope and valley bottom. Results of laboratory analysis and fertility capability classification (FCC) showed that the soils were predominantly sandy in texture, strongly acidic (pH 3.3 – 4.3) and low in the following fertility parameters – organic matter content (1.00-1.28%), total nitrogen (N) (0.043 – 0.057%), effective cation exchange capacity (ECEC) (2.38-6.02 $cmol_c\ kg^{-1}$), base saturation (56-71%), exchangeable K (0.038-0.090 $cmol_c\ kg^{-1}$) and available phosphorus (P) (4.60-13.12 $mgkg^{-1}$). Based on Soil Taxonomy, soils in the area belonged to two soil orders – Entisols (44.4%) and Inceptisols (55.6%). Also, results of land suitability evaluation (LSE) revealed the land to be marginally suitable (S3) for oil palm, rubber and upland rice cultivation, moderately suitable (S2) for cocoa and cashew and highly suitable (S1) for coconut cultivation. Major crop production constraints were soil physical characteristics (texture/structure) and fertility. To raise land productivity, management techniques should include application of organic fertilizers to enhance nutrient holding capacity of the soils and supply deficient basic cations. Regular soil testing for proper fertilizer application to ensure a balance nutrient application is also recommended.

Keywords: Agricultural potential, beach ridge sands, Niger Delta, Nigeria, soil characteristics

INTRODUCTION

The ability of any soil to supply the required quantity of plant nutrients is mostly affected by the soil genetic composition (parent material), the degree to which the parent material has been altered by the forces of weathering and the management of the soil by man. Therefore, the soil productive potential and its resilience to amendment and management for sustainable agricultural production depend largely on the soil parent material (Ajiboye and Ogunwale 2010).

*Corresponding author : E-mail: drbasseyudoh@yahoo.com

In order to accurately classify a soil and make recommendations for utilitarian purposes, soils occupying any particular agro-ecological zone must be properly characterized (Brady 1990; Esu 2005). Information on the kinds of soils in an area is obtained through soil survey activities. Soil survey identifies, characterizes and classifies the soils in the survey areas, showing their extent and distribution on a map (SCS News 1984). Land evaluation is the process of estimating the potential of a land for alternative uses (FAO 1976). Application of the Food and Agriculture Organization (FAO) framework for land evaluation can identify the most limiting land qualities and characteristics and provide a good basis for advising farmers on appropriate management practice for optimum production in a particular agro-ecological zone (Chinene 1992).

Most agricultural soils in Akwa Ibom State, Nigeria, put to arable crop production are developed from parent materials which are grouped into coastal plain sands, beach ridge sands, sandstone and alluvial deposits. The characteristics of these soils are largely determined by these original materials and influenced by climate, topography and the general agricultural land use pattern and management (Ibia and Udo 2009).

The parent materials of the beach ridge sands are fluvio-marine deposits of unconsolidated sands deposited by tidal waters along the fringes of the Atlantic ocean and in estuaries of the various rivers. They are therefore found in those states (Rivers, Akwa Ibom and Cross River) which border the coast (FMANR 1990). Tahal Consultants (1982) observed that in the southern coastal areas along the bight of Bonny, fine sandy coastal beach ridges occupy about 560 square kilometers within the Qua Iboe River Basin.

The beach ridge sands soils, like other 'acid sands' of southern Nigeria are fragile, acidic and low in native fertility (Udo and Sobulo 1981); nevertheless, they support a very high population density in the country. Due to the very poor agricultural productivity of the beach ridge sands, they are not intensively cultivated by farmers who seem to regard these areas as marginal lands because of lack of knowledge and appropriate technology for managing them for optimum productivity.

Therefore, the very low fertility status of these soils, harsh climatic conditions, proneness to pollution due to oil exploration and the dense population they support, call for special attention to their proper management for agriculture and human settlement. The current shortage of food and the increasing food requirements of the rapidly expanding population necessitate that marginal lands such as the beach ridges hitherto left under-utilized, be brought under intensive agricultural land use, and commercially oriented permanent farming as opposed to shifting cultivation (Ojanuga 2006).

However, available information on the beach sands soils is insufficient for efficient scientific planning for the future use of the soils for agriculture. A clear understanding of the relationship of land qualities/characteristics to land use is essential for the formulation of meaningful guidelines for efficient land use policies and ultimately increased productivity of the reach ridge sands and conservation of natural resources.

In view of the above, the present study was therefore carried out with the following objectives:

a. To characterize and classify soils derived from the beach ridge sands in the coastal (southernmost) areas of Akwa Ibom State, Nigeria
b. To carry out fertility capability classification of soils identified in the area.
c. To evaluate the agricultural potential of the soils in terms of their suitability for the cultivation of certain crops of economic importance, namely, oil palm *(Elaeis guineensis)*, cashew nut *(Anacardium occidentalis)* cocoa *(Theobroma cacao)*, coconut palm *(cocos nucifera)*, rubber *(Hevea brassilienesis)* and upland rice *(Oryza sativa)*
d. To recommend measures that would ensure optimum and sustainable agricultural productivity of these soils.

METHODOLOGY

Study Area

The study was conducted in the southernmost part of Akwa Ibom State of Nigeria, comprising mainly the coastal areas of Ikot Abasi, Eastern Obolo, Esit Eket, Eket, Mkpat Enin, Onna, Ibeno and Mbo Local Government Areas. The area is located within latitudes 4°35' and 4°40' N and between longitudes 7°30' and 8°15' E. (*Fig. 1*).

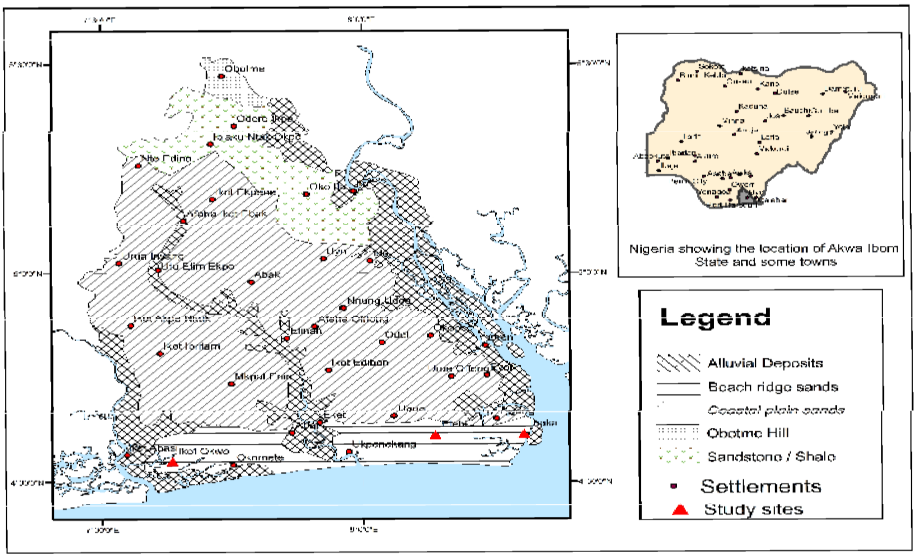

Fig. 1: Akwa Ibom State showing the beach ridge sands and other parent materials

The climate is humid tropical with an annual rainfall of about 3000 mm. The area has a bimodial rainfall pattern with peaks around July and September with almost no month without rainfall. Mean annual maximum and minimum temperatures are about 29 ^{o}C and 24 ^{o}C, respectively (Petters *et al*. 1989). Relative humidity ranges from 80 to 90%. The natural rainforest vegetation has lost its original nature due to anthropogenic activities arising from population increase. In the narrow valleys where the soils are hydromorphic, the terrain is covered by natural vegetation of shrubs and bush. Where the soils are better drained, there are cultivated areas, mainly cassava. The area generally comprises a low lying delta plain underlain mainly by beach ridge sands and Holocene Fluviomarine deposits (Udo and Sobulo 1981).

Field Studies

Three study sites (toposequences) were selected to represent the area of study as follows: Ikot Okwo (IKW) Etebi (ETB) and Ibaka (IBK) in Ikot Abasi, Esit Eket and Mbo Local Government Areas, respectively (*Fig. 1*). Along each toposequence, profile pits were located, one each at the crest, middle slope and valley bottom, respectively. Each pit was described according to FAO Guidelines for soil description (FAO 2006) and sampled by genetic horizons for laboratory analysis.

Laboratory Analysis and Soil Classification

Laboratory analyses of soil samples were carried out using appropriate standard procedures (IITA 1979; Udo and Ogunwale 1986; Udo *et al*. 2009). The following parameters were analysed: particle size distribution, soil reaction (pH), electrical conductivity, organic carbon, total nitrogen, available phosphorus, exchangeable bases, exchangeable acidity and available micronutrients. Effective cation exchange capacity (ECEC) was determined as the summation of exchangeable cations (Ca, Mg, K, Na) and exchangeable acidity (Al^{3+} + H^{+}). Using appropriate formulas/methods, base saturation (BS), exchangeable sodium percentage (ESP) and carbon/nitrogen (C/N) ratio were also determined.

From the results of the laboratory analyses and field morphological properties, the nine pedons identified in the study area were classified following Soil Taxonomy (Soil Survey Staff 2010) and correlated with FAO/UNESCO Legend (IUSS / WRB 2006).

Land Evaluation

The potential and limitations of five land qualities / characteristics (climate, topography, wetness, soil physical characteristics and soil fertility) in determining the suitability of the nine pedons (identified in the study area) for oil palm, coconut palm, cashew nut, cocoa, rubber and upland rice cultivation were evaluated using the FAO Land Suitability Evaluation (LSE) (FAO 1976) system. Also, the Fertility Capability Classification (FCC) system was used to classify the soils according to the kinds of problems they present for agronomic management of the chemical and physical properties. The FCC system adopted was the Sanchez *et al*. (1982) version.

RESULTS AND DISCUSSION

Land Qualities/Characteristics of Pedons in the Study Area

Some important morphological, physical and chemical properties of soils derived from the beach ridge sands (BRS) are presented in Tables 1 (a,b,c) and 4. The soils were generally deep (>200 cm) irrespective of site, except for the valley bottom soils which had a high water table. They were non-concretionary and fairly well drained. The soil colours for Ikot Okwo pedons were dark brown (7.5YR 4/4) topsoil over reddish yellow (7.5YR 6/8) subsoil at the crest and dark brown over yellow (10YR 7/8) subsoil at both the middle slope and valley. For Etebi (ETB), the topsoils were very dark brown (10YR 3/3) over brownish yellow (10YR 6/6) subsoil at the crest; dark brown (7.5 YR 3/2) topsoil over yellowish brown (10YR 5/6) subsoil at the middle slope and dark yellowish brown (10YR 4/4) topsoil/ subsoil at the valley (Table 1). Finally, for Ibaka (IBK), the colours were very pale brown (10YR 7/3) topsoil over brownish yellow (10YR 6/8) subsoil at the crest, brown (10YR 6/8) at the middle slope and dark brown (10YR 3/3) over brown (10 YR 4/3) subsoil. Variation in soil colour indicates differences in soil moisture and drainage conditions as influenced by topography (Buol *et al.* 1989; Tahal Consultants 1982).

The soils were weak/moderately well structured. The topsoils had either fine, medium or coarse granular or crumb structure, while the subsoils had a medium subangular blocky structure (Table 4). All the pedons belonged to the sand textural class. Most of the pedons (67%) were dominated by fine sand fraction (ranging from 47 to 84%), while three pedons (33%) were dominated by coarse sand fraction (ranging from 68 to 81%). These results are in line with earlier observations on this area by Tahal Consultants (1982) and Udo (2001) that the texture of the soils of the beach ridge sands is characterized by very fine loose sands having a high infiltration capacity.

The results in Table 4 also show that soil pH in the study area ranged from 3.27 to 4.35 indicating strongly acidic soils. The very low pH is explained by the fact that these soils are influenced by salt water marshes (of the Atlantic Ocean). Thus when air penetrates, the pyrites are oxidized to basic ferric sulphates and H2SO4 producing acid sulphate soils (Ojanuga *et al*. 2003). Organic matter was low (<2.00%) in most of the soils. Available P was low to medium (6.33 – 13.11 $mgkg^{-1}$). Exchangeable cations (K, Ca, Mg, and Na) were low resulting in low ECEC (ranging from 2.89 to 5.27 $cmol_c\ kg^{-1}$) and low base saturation (ranging from 56.18 to 71.16%).

This result confirms earlier findings and observations of other workers concerning the characteristics of soils in the area (Udo and Sobulo 1981; Tahal Consultants 1982; FMANR 1989; Petters *et al*. 1989 and Udo 2001). The result shows the effect of high rainfall experienced in the area combined with coarse and loosed textured soils which are highly susceptible to leaching. This has resulted in the leaching of most of the basic cations resulting in the observed low ECEC, low base status, high exchangeable acidity and the overall low nutrient status of the soils.

TABLE 1a
Some profile characteristics of soils of the beach ridge sands (IKW)

Pedon	Horizon designation	Depth (cm)	B. Sat (%)	ECEC $cmol_c kg^{-1}$	Coarse sand (%)	Fine sand (%)	Total sand (%)	% Slit	Clay (%)	Textural class	Soil colour (topsoil / subsoil
IKW 1	AP	0 - 20	69.87	2.69	23 82	65.50	89.32	5.94	4.74	S	7.5YR4/4
	AB	20 - 52	68.31	2.43	30.48	56.86	87.32	5.94	6.74	LS	
	BI	52 -72	61.81	3.06	46.78	36.54	83.32	5.94	10.74	LS	7.5YR6/8
	B2	72 -117	61.30	3.07	47.12	42.20	89.32	5.94	4.74	S	
	C1	117-147	71.50	2.95	45.20	46.06	91.26	3.94	4.80	S	
	C2	147.202	62.23	3.39	46.00	43.26	89.26	5.94	4.80	S	
IKW 2	AP	0 -2	56.73	3.33	23.52	71.60	95.14	0.06	4.80	S	
	B1	21-56	59.52	3.56	40.76	46.50	87.26	5.94	6.80	LS	7.5YR 3/3
	B2	56-85	56.85	2.96	30.42	48.84	79.26	5.94	14.80	SL	
	B3	85-110	70.40	2.38	35.78	51.48	87.26	3 94	6.80	LS	
	C1	110-150	70.40	2.38	35.24	54.02	89.26	3.94	6.80	S	10YR 7/8
	C2	150-205	75.08	2.81	29.18	58.08	87.26	5 94	6.80	L S	
IKW 3	AP	0-24	72.29	2.92	32.88	56.44	89.32	5 94	4.74	LS	7.5YR4/2
	BA	24-50	62.26	3.39	20.18	71.14	91.32	3 94	4.74	S	
	B1	50-57	61.75	3.77	21.36	67.96	89.32	3 94	6.74	LS	7.5YR7/8
	B2	67-106	81.61	3.15	38.56	48.76	87.32	5 94	6.74	LS	
	C1	106-145	81.61	3.15	32.54	56.78	89.32	5 94	6.74	LS	
	C2	145-152	62.09	3.80	14.94	70.38	85.32	5 94	8.74	LS	

S = sand, LS = loamy sand; IKW = Ikot Okwo; 1 = hill crest; 2 = middle slope, 3 = valley

TABLE 1b
Some profile characteristics of soils of the beach ridge sands (ETB)

Pedon	Horizon designation	Depth (cm)	B. Sat (%)	ECEC $cmol_c\,kg^{-1}$	Course sand (%)	Fine sand (%)	Total sand (%)	Slit (%)	Clay (%)	Textural class	Soil colour (topsoil / Subsoil)
ETB 1	AP	0-33	65.74	6.02	81.34	7.32	88.66	6.24	5.10	S	
	B_1	33-62	39.49	5.31	70.16	18.50	88.66	4.30	7.04	LS	10YR 2/3
	B_2	62-110	60.90	5.73	50.54	36.12	86.66	6.30	10.74	LS	
	BC	110-165	57.36	4.50	74.02	16.64	90.66	0.30	9.04	S	10YR 6/6
	C	165-200	57.37	4.88	53.66	23.00	86.66	2.30	11.04	LS	
ETB 2	Ap	0-30	69.83	5.30	86.00	8.78	94.78	0.24	4.98	S	
	B	30-60	60.84	5.31	82.10	7.15	89.26	3.76	6.98	S	7.5YR 3/2
	BC	60-77	57.29	4.50	75.00	9.66	83.66	6.30	9.04	LS	
	C	77-140	67.69	4.46	51.70	32.96	84.66	4.30	11.04	LS	10YR 5/6
ETB 3	Ap_1	0-10	61.23	4.95	89.26	4.56	93.82	0.72	5.46	S	
	AP_2	10-20	63.75	4.77	67.96	15.30	83.26	9.28	7.46	LS	10YR 4/4
	AB	20-32	66.67	5.22	71.80	17.46	89.26	5.28	5.46	S	
	B	32-51	61.09	5.35	72.60	12.66	85.26	7.28	7.46	LS	10YR 4/4
	BC	51-62	65.53	4.64	78.56	8.70	87.26	5.76	6.98	LS	
	C	62-100	51.32	4.60	60.56	34.22	94.78	0.24	4.98	S	

S = sand, LS = loamy sand; ETB = Etebi; 1 = hill crest, 2 = middle slope, 3 = valley.

TABLE 1c

Some profile characteristics of soils of the beach ridge sands (IBK)

Pedon	Horizon designation	Depth (cm)	B. Sat (%)	ECEC $cmol_c\,kg^{-1}$	Course sand (%)	Fine sand (%)	Total sand (%)	Slit (%)	Clay (%)	Textural class	Soil colour (topsoil / subsoil)
IBK 1	Ap	0-22	61.15	3.86	16.36	76.90	93.26	1.94	4.80	S	10 YR7/3
	BA	22-46	57.26	4.49	55.12	40.02	95.32	0.06	4.62	S	
	B	46-87	61.18	3.84	45.52	49.62	95.14	0.06	4.8	S	10 YR 6/8
	C_1	87-136	56.77	3.70	42.16	53.14	95.32	0.06	4.62	S	
	C_2	136-208	60.65	3.58	10.16	84.98	95.14	0.06	4.8	S	
IBK 2	Ap	0-26	61.15	3.86	21.36	71.70	93.26	1.94	4.8	S	
	AB	26-59	68.05	5.10	34.72	56.54	91.26	3.94	4.8	S	10 YR4/3
	B	59-111	68.97	4.02	31.10	58.34	89.44	5.84	4.62	S	
	BC	111-150	64.15	4.01	16.88	74.56	91.44	3.94	4.62	S	10 YR 6/8
	C	150-213	59.21	3.58	1.30	96.44	97.74	0.06	4.8	S	
IBK 3	Ap_1	0-12	61.86	3.07	31.64	63.68	95.32	0.06	4.62	S	
	Ap_2	12-30	51.81	4.58	27.86	63.58	91.44	3.94	4.62	S	10 YR3/3
	B	30-48	68.97	4.63	31.40	58.04	89.44	5.94	4.62	S	
	C	48-80	67.07	3.49	38.94	54.32	93.26	1.94	4.8	S	10 YR 4/3

S = sand; IBK = Ibaka; 1 = crest; 2 = middle slope; 3 = valley

Soil Classification

The classification of the nine pedons from the three study sites (IKW, ETB and IBK) representing the area of study is shown in Table 2, while some characteristics of the pedons are shown in Tables 1a, b, c. The nine pedons were classified following the criteria outlined in the USDA Soil Taxonomy (Soil Survey Staff 2010) and correlated with World Reference Base (WRB) for Soil Resources (IUSS/WRB 2007) system.

Pedons were classified into order, suborder, great group and subgroup, mainly on the basis of diagnostic horizons, the properties of the soils that reflect the nature of the soil environment and the dominant pedogenic processes that are responsible for the soil formation (Ajiboye and Ogunwale 2010). Generally, the results of field study of profile pits and laboratory analysis showed that all the soils were relatively young (Unyienyin 2010). They all lacked argillic or kandic horizons. However, based on the stage of profile development, soils in the entire area could be placed in either the Inceptisoils or Entisols soil orders (Soil Survey Staff 2010) which correlate with Cambisols and Regosols, respectively (IUSS/WRB, 2007). Five pedons (or 56% of the area), representing the crest and middle slope in IKW, and all pedons (crest, middle slope and valley) in ETB with moderate weathering but having features of cambic B horizon were classified as Inceptisols (Cambisols). On the other hand, four pedons (or 44% of the area), representing the valley in IKW and all the pedons (crest, middle slope and valley) in IBK qualified as Entisols (Regosols), being very young soils with no diagnostic horizon development.

Three of the Inceptisols were placed in Typic Dystrudepts subgroup (Table 2), based on the moisture regime, low pH and low base (Soil Survey Staff 2010), while two Inceptisols qualified as Aeric Endoaquepts as they had a relatively higher water table resulting in poor drainage conditions. Similarly, the Entisols were divided into two subgroups – Typic Psammaquent and Typic Udipsamments (Table 2). Both had sandy texture, but whereas the Psammaquents had high, water table, poor drainage and were wet at certain periods of the year, the Udipsamments were relatively drier (under humid conditions). Earlier workers had similarly described beach ridge soils as young soils derived from recently deposited materials (Jungerius 1964). Similarly, Petters *et al*. (1989) classified beach ridge soils as Typic Tropopsamments, Typic Tropoaquent (Dystric Regosols) and Oxic Dystropepts (Dystric Cambisols).

Agricultural Potential of Soils of the Beach Ridge Sands

Fertility Capability Classification

The result of fertility capability classification of the soils in the study area is shown in Table 3. The conversion data used in evaluating the soils are as outlined by Sanchez et al. (1982). The system consists of three categorical levels: 'type' (texture of plough layer or top 20 cm); substrata type' (texture of subsoils) and 'modifiers' (soil properties or conditions which act as constraints

TABLE 2
Classification of soils of the beach ridge sands

	Classification		
	USDA(Soil Survey Staff, 2010)		WRB (FAO)
Pedon*	Order	Subgroup	
IKW 1	Inceptisols	*Typic Dystrudepts*	*Haplic Cambisols (Dystric)*
IKW 2	Inceptisols	*Typic Dystrudepts*	*Haplic Cambisols (Dystric)*
IKW 3	Entisols	*Typic Psammaqnents*	*Endogleyic Regosols (Dystric)*
ETB 1	Inceptisols	*Typic Dystrudepts*	*Haplic Cambisols (Dystric)*
ETB 2	Inceptisols	*Aeric Endoaquepts*	*Endogleyic Cambisols (Dystric)*
ETB 3	Inceptisols	*Aeric Endoaquepts*	*Endogleyic Cambisols (Dystric)*
ETB 1	Entisols	*Typic Udipsammerts*	*Haplic Regosols (Dystric)*
ETB 2	Entisols	*Typic Udipsammerts*	*Haplic Regosols (Dystric)*
ETB 3	Entisols	*Typic Psammaquents*	*Endogleyic Regosols (Dystric)*

*IKW = Ikot Okwo; ETB = Etebi; IBK = Ibaka
1 = hill crest, 2= middle slope, 3 = valley.

TABLE 3
Fertility capability classification * (FCC) of pedons derived from beach ridge sands

Pedon	Type[1]	Substrata [2]	………… Condition modifiers[3]													…………………..…	FCC Unit
		Type	g	d	k	e	a	h	b	i	x	v	s	n	c	%	
IKW 1	S	S	-	-	+	+	-	+	-	-	-	-	-	-	-	0-2	Sehk
IKW 2	S	S	-	-	+	+	-	+	-	-	-	-	-	-	-	6-13	Sehk
IKW 3	S	S	-	-	+	+	-	+	-	-	-	-	-	-	-	0-2	Sehk
ETB 1	S	S	-	-	+	+	-	+	-	-	-	-	-	-	-	0-2	Sehk
ETB 2	S	S	-	-	+	+	-	+	-	-	-	-	-	-	-	4-6	Sehk
ETB 3	S	S	-	-	+	+	-	+	-	-	-	-	-	-	-	2-4	Sehk
IBK 1	S	S	-	-	+	+	-	+	-	-	-	-	-	-	-	0-2	Sehk
IBK 2	S	S	-	-	+	+	-	+	-	-	-	-	-	-	-	6-13	Sehk
IBK 3	S	S	-	-	+	+	-	+	-	-	-	-	-	-	-	0-2	Sehk

*After Sanchez et al. (1982)

1. Type = texture of topsoil;
2. Substrate Type = texture of subsoil
3. Condition modifiers = Crop production constraints (k = exchangeable potassium (K) deficiency; e = low cation exchange capacity (CEC); h = acidic reaction ; % = slope of the land.

TABLE 4
Land qualities /characteristics of pedons of the beach ridge sands

Land qualities/ characteristics		←				Pedons →				
1. Climate (c):	Unit	IKW 1	IKW 2	IKW3	ETB 1	ETB 2	ETB 3	IBK 1	IBK 2	IBK 3
Annual rainfall	mm	2584.2	2584.2	2584.2	2584.2	2584.2	2584.2	2584.2	2584.2	2584.2
Mean temperature	^{0}C	27.8	27.8	27.8	27.8	27.8	27.8	27.8	27.8	27.8
Relative humidity	%	88	88	88	89	89	89	89	89	89
Solar radiation	$NJM^{-2}day^{-1}$	114	114	114	114	114	114	114	114	114
2. Soil physical characteristics (s):										
Soil Depth	cm	202	205	152	200	140	100	208	213	80
Fine sand	%	63.27	47.40	63.25	20.06	13.82	10.32	83.66	68.05	70.26
Coarse sand	%	23.82	40.12	27.10	68.35	74.60	80.88	9.60	23.65	22.62
Total sand	%	87.09	87.52	90.35	88.41	88.42	91.20	93.26	91.70	92.88
Silt	%	5.99	3.70	4.72	5.27	5.26	1.95	1.86	3.60	2.49
Clay	%	6.92	8.78	4.93	6.32	6.32	6.85	4.88	4.70	4.63
Texture	-	Sand	sand	sand	sand	sand	Sand	sand	sand	sand
Structure		f,gr;m;sbk	M,gr,sbk	c,gr,msbk	f,cr;msbk	f,cr,csbk	c,gr	f,cr,m,sbk	f,cr;msbk	f,cr;m,sbk
3. Topography (t)										
Slope	%	0-2	6-13	0-2	0-2	3-8	0-2	0-2	6-13	0-2
4. Wetness (w) (or Ground Water Table)										
Drainage	-	2	3	3	3	3	3	2	3	3
Flood duration	months	-	-	-	-	-	-	-	-	-
Ground water table	cm	NE	NE	152	NE	140	100	NE	NE	80

TABLE 4
Land qualities /characteristics of pedons of the beach ridge sands (continued)

Land qualities/ characteristics		Pedons								
	Unit	IKW 1	IKW 2	IKW3	ETB 1	ETB 2	ETB 3	IBK 1	IBK 2	IBK 3
5. Fertility (f)										
pH	-	3.71	4.35	3.42	4.04	3.96	3.86	3.54	3.27	3.61
Total N	%	0.043	0.52	0.043	0.045	0.046	0.049	0.048	0.045	0.040
Organic Matter	%	1.91	2.08	1.76	1.82	1.85	2.94	1.98	1.79	2.00
Available P	$mgkg^{-1}$	6.33	12.11	8.61	13.11	8.28	10.48	9.59	8.03	10.48
Exchangeable K	$cmol_c kg^{-1}$	0.077	0.075	0.068	0.076	0.069	0.071	0.058	0.032	0.060
Exchangeable Ca	$cmol_c kg^{-1}$	1.00	1.11	1.25	2.49	2.66	1.98	1.45	1.69	1.30
Exchangeable Mg	$cmol_c kg^{-1}$	0.73	0.31	0.72	1.15	1.67	1.37	0.31	1.31	0.33
Exchangeable Na	$cmol_c kg^{-1}$	0.046	0.056	0.048	0.054	0.046	0.052	0.045	0.040	0.055
CEC (Soil)	$cmol_c kg^{-1}$	2.93	2.89	3.36	5.27	4.88	4.92	3.88	4.11	3.18
Base Saturation	%	65	62	68	50	64	60	58	63	62
Toxicity (t)										
Available Fe	$mg\ kg^{-1}$	21.02	25.40	19.93	20.44	24.89	21.79	19.43	37.34	22.23
Available Mn	$mg\ kg^{-1}$	1.7	1.3	1.29	1.85	1.76	6.61	1.43	1.42	1.39
Available Zn	$mg\ kg^{-1}$	3.1	2.8	2.25	2.94	2.46	2.70	3.73	2.66	1.79
Available Ca	$mg\ kg^{-1}$	1.7	1.39	1.28	0.86	0.96	0.84	1.24	1.05	0.91
Salinity / alkalinity (n)										
EC (means)	$mS\ cm^{-1}$	0.046	0.243	0.049	0.092	0.11	0.077	0.035	0.049	0.035

Key:

Structure: f, gr = fine, granular; m, sbk = medium, subangular blocky;
m, gr = m, granular; f, cr = fine, crumb; c, sbk = coarse, subangular blocky; c, gr = coarse, granular.

Drainage/ground water table: 2 = well drained, 3 = fairly well drained; NE = not encountered.

to crop performance). Class designations from the three categorical levels are combined to form a FCC unit. Thus, the soils were classified according to whether a characteristic was present or not. The FCC units of the nine pedons from the beach ridge sands were determined based on the soil profile characteristics. Each FCC unit lists the 'type' and 'substrata type' (which was the same as the type in this study) in capital letters, and the modifiers in lower case letters.

The result of FCC in Table 3 shows that all the nine pedons in the study area have the same FCC unit, SehK (except for the variation in topographic positions or slope). The results show that the soils are generally characterized by uniformly sandy profiles (top and sub-soils), represented by S; they have low cation exchange capacity (CEC), represented by e; they have acidic reaction, represented by h; and are deficient in exchangeable potassium, which is represented by K. These results are presented in the summary with the kinds of problems presented by the beach ridge soils for agronomic management of their chemical and physical properties (Boul *et al*. 1975; Sanchez *et al.* 1982).

Land Suitability Evaluation

The potential (and limitations) of some land qualities/characteristics (climate, soil physical characteristics, topography, wetness or ground water table, fertility and salinity/alkalinity) in determining the suitability of the nine pedons (representing the area of study) for the cultivation of some important economic crops (oil palm, cocoa, cashew, coconut, rubber and upland rice) was evaluated. The evaluation was carried out following the conventional method of the FAO (1976) framework for land evaluation.

The determination of land suitability involved the matching of the land qualities/characteristics (Table 4) with the established requirements (Sys 1985; Ogunkunle 1993) for each of the crops (oil palm, cocoa, cashew, coconut, rubber and upland rice). After matching the land quality/characteristics with the land requirement for the crop, depending on the extent to which the land quality/characteristic satisfied the requirement, each limiting characteristic was rated (Table 5). For the non-parametric evaluation (the method reported here), the final (aggregate) suitability class in Table 6 is indicated by the most limiting land quality/characteristics of the pedon (FAO 1976).

Results of Matching Land Requirements for Crop Cultivation with Land Qualities/Characteristics: Oil Palm

Climate (c)

The class score (rating) of the nine pedons in the study area (Table 5), shows that the area is climatically suitable for oil palm, being optimal (100% suitable) in terms of annual rainfall and relative humidity and nearly optimal (95% suitable) in terms of mean temperature.

TABLE 5

Suitability Class scores of pedons of beach ridge sands for oil palm cultivation

Land Qualities	Pedons								
	IKW 1	IKW 2	IKW 3	ETB 1	ETB 2	ETB 3	IBK 1	IBK 2	IBK 3
Climate (c)									
Annual rainfall (mm)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)
Mean temperature(%)	S1(95)	S1(95)	S1(95)	S1(95)	S1(95)	S1(95)	S1(95)	S1(95)	S1(95)
Relative Humidity(%)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)
Topography (t)									
Slope %	S1(100)	S2(80)	S1(100)	S1(100)	S2(80)	S1(100)	S1(100)	S1(80)	S1(100)
Wetness (w)									
Drainage	S1(100)	S1(100)	S3(40)	32(100)	S1(100)	S3(40)	S1(100)	S1(100)	S3(40)
Soil physical characteristics (s)									
Texture	S3(40)	S3(40)	S3(40)	S3(40)	S3(40)	S3(40)	S3(40)	S3(40)	S3(40)
Structure	S3(40)	S2(80)	S2(80)	S2(80)	S2(80)	S3(40)	S2(80)	S2(80)	S3(40)
Depth (cm)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S3(60)
Fertility (f)									
Apparent CEC	S1(95)	S1(95)	S1(95)	S1(95)	S1(95)	S1(95)	S1(95)	S1(95)	S1(95)
Base Saturation	S1(95)	S1(95)	S1(95)	S1(95)	S1(95)	S1(95)	S1(95)	S1(95)	S1(95)
pH	S3(40)	S3(40)	S3(40)	S3(40)	S3(40)	S3(40)	S3(40)	S3(40)	S3(40)
Organic cation	S2(80)	S2(80)	S2(80)	S2(80)	S2(80)	S2(80)	S2(80)	S2(80)	S2(80)
K (mole fraction)	S3(40)	S3(40)	S3(40)	S3(40)	S3(40)	S3(40)	S3(40)	S3(40)	S3(40)
Mg: k ratio	S1(95)	S1(95)	S1(95)	S1(95)	S1(95)	S1(95)	S1(95)	S1(95)	S1(95)
Salinity /Alkalinity (n)									
EC (mS/cm)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)
Aggregates stability	S3sf	S3sf	S3sf	S3sf	S3sf	S3sf	S3sf	S3sf	S3sf

Aggregate suitability class score:

100-75=S1; 74-50=S2; 49-25=S3; 24-15=N1; 14-0=N2; s = soil physical characteristic limitation; f = soil fertility limitation

Topography (t) and Drainage (w)
In terms of topography (slope), six pedons were optimal while three pedons (IKW 2, ETB 2 and IBK 2) were sub-optimal (80% suitable) for oil palm cultivation because they had slopes > 4% (Sys, 1985). In terms of drainage, six of the pedons were optimal while three were only marginally suitable for oil palm cultivation (Table 6). This shows that topography and drainage are not very serious limitations to oil palm cultivation in the area.

Soil Physical Characteristics (s)
Soil depth as one of the physical characteristics was optimal in the entire area except for one pedon (IBK 3) which was sub-optimal (60% suitable). However, soil texture (and structure) was the most limiting of the soil physical characteristics. Soil texture for optimum productivity of oil palm should be clay loam, sandy clay loam or loam (Sys 1985), but the texture for all the pedons in the area was sand/ loamy sand (Table 4). This has rendered the entire area only marginally suitable for oil palm cultivation and constitutes a major constraint to oil palm production (Table 6).

Fertility (f) and Salinity / Alkalinity (n)
Soil fertility is another serious constraint limiting oil palm cultivation on the beach ridge sands soils. Although cation exchange capacity (CEC), base saturation, organic carbon and Mg:K ratio were rated sub-optimal (95/80% suitable), soil pH and K (mole fraction) were grossly inadequate (40% suitable; Table 5), thereby rendering the whole area only marginally suitable for oil palm cultivation. But in terms of salinity/alkalinity, the entire area was rated optimal (100% suitable) for oil palm cultivation.

Aggregate Suitability for Cultivation of Oil Palm, Cocoa, Cashew, Coconut, Rubber and Upland Rice

The individual ratings of the land characteristics for each pedon for oil palm cultivation is shown in Table 5, while Table 6 shows the aggregate suitability classification of each pedon for each of the six crops: oil palm and five others (cocoa, cashew, coconut, rubber and upland rice) which were also evaluated in a similar method.

In this study, aggregate suitability classes S1 (highly suitable), S2 (moderately suitable), S3 (marginally suitable) N1 (currently not suitable) and N2 (permanently not suitable), are equivalents of suitability class scores (ratings) 100-75, 74-50, 49-25, 24-15, 14-0, respectively. This study adopted the conventional (FAO, 1976) method, in which case just one characteristic, that is, least suitable decides the aggregate suitability class of a pedon. Accordingly, all the pedons in the study area were classified as marginally suitable (S3) for oil palm cultivation because of the severity of soil physical characteristic (s) and fertility (f) limitations.

TABLE 6

Suitability classification of beach ridge sands pedons for six crops, indicating limiting characteristics

Pedon	Crop type/suitability class					
	Oil Palm	Cocoa	Rubber	Cashew	Coconut	Upland Rice
IKW 1	S3 s,f	S2s, f	S3f	S2s	S1	S3w
IKW 2	S3 s,f	S2s, f	S3f	S2t,s	S2t	S3w,s
IKW 3	S3 s,f	S3s, f	S3f	S2w,s	S1	S3s
ETB 1	S3 s,f	S2s, f	S3f	S2w,s	S1	S2 s,f
ETB 2	S3 s,f	S2s, f	S3f	S2w,s	S1	S3s
ETB 3	S3 s,f	S2w,s	S3f	S2w,s	S1	S3s
IBK 1	S3 s,f	S2s,f	S2s,f	S2s	S1	S3w,s
IBK 2	S3 s.f	S3,s	S3f	S2t,s	S2t,s	S3w.s
IBK 3	S3s,f	S3 w,s	S3f	S2w,s	S1	S3s

SI = highly suitable; S2 = moderately suitable; S3 = marginally suitable

f = fertility limitation; s = soil physical characteristic limitation, t = topographic (slope) limitation; w = soil wetness (drainage) limitation.

As shown in Table 6, similar evaluations as in the case of oil palm were done for cocoa, rubber, cashew, coconut and upland rice. The results showed that as in the case of oil palm, the land was also marginally suitable for rubber cultivation, with fertility being the most serious constraint to cultivation. Except for pedon ETB 1 (which was moderately suitable), the land was also marginally suitable for upland rice with soil drainage (w), physical characteristic (s) and fertility (f) being serious constraints to upland rice cultivation. For cocoa cultivation, six pedons (67% of the area) were moderately suitable (S2) while three pedons, IKW 3, IBK 2, IBK 3 (33% of the area), were marginally suitable. The most serious constraints were soil physical characteristics, fertility and drainage.

The results of the evaluation (Table 6) further showed that soils of the beach ridge sands were more favourable to the production of cashew. All the pedons were classified as moderately suitable (S2) for cashew cultivation, with soil physical characteristics, topography and soil drainage being moderate constraints to its production. However, the crop most favoured by the land qualities/characteristics of soils derived from the beach ridge sands was coconut. Seven of the pedons (representing 78% of the area) were classified as highly suitable (S1), while two pedons, IKW 2 and IBK2 (22% of the area), were classified as moderately suitable (S2), because of topographic or slope (t) constraints.

Soil Management for Optimum and Sustainable Crop Production

The result of this study and previous works (Tahal Consultants 1982, Petters *et al.* 1989; Udo, 2001) have shown that soils of the beach ridge sands are generally coarse textured. Since they are located in high rainfall areas, they are strongly leached and deprived of basic cations (Enwezor *et al*. 1981). Also, due to the presence of pyrites (Ojanuga *et al.* 2003), they are strongly acidic. Furthermore, the loose nature of the soils makes them very susceptible to water erosion. High acidity, low CEC and low buffering capacity results in low fertility status, multiple nutrient deficiency and nutrient imbalance, characteristics which are common to these soils.

The major management constraints are therefore soil acidity, multiple nutrient requirements, nutrient imbalance and soil erosion. To raise the productivity of these soils and also sustain their productive potential, an integrated nutrient management system, which adopts an ecological approach, will be most appropriate. This approach involves the wise use and management of inorganic and organic nutrient sources in an ecologically sound production system (Ajiboye and Ogunwale 2010). Judicious lime application may be required to supply deficient basic cations and thus raise the base saturation of these soils.

The role of organic matter/organo-mineral fertilizers is crucial in the management of these soils. Not only will it improve the physical properties of the soils and reduce erosion, it will also serve as a major reservoir of plant nutrients. Therefore, whatever may be the farming system adopted, a reasonable level of organic matter should be maintained at all times by use of farm yard or green manure. Also, regular soil testing should be carried out for proper fertiliser recommendations to ensure balanced soil nutrient application.

CONCLUSION

Parent material soils of the beach ridge sands are generally coarse textured, loose, highly leached, strongly acidic and low in native fertility. They are marginally suitable for oil palm, rubber and upland rice cultivation because of serious fertility and physical characteristic constraints. The soils are moderately suitable for cocoa and cashew cultivation with constraints related to soil drainage, fertility, and physical characteristics. However, the soils are highly suitable for coconut cultivation.

To raise the productivity of these soils to optimum and also maintain it for sustainable crop production, integrated nutrient management, involving the use of organic/organo-mineral fertilizers, with regular soil testing for a balanced nutrient application is recommended. For effective results, an ecological approach to the management of soils derived from the beach ridge sands in the Niger Delta Region of Nigeria is most appropriate.

REFERENCES

Ajiboye, G. A. and J. A. Ogunwale, 2010. Characteristics and classification of soils developed over talc at Ejiba, Kogi State. Nigeria. *Nigerian Journal of Soil Science*. 20: 1-14.

Brady, N. C. 1990. *The Nature and Properties of Soils* (10th ed.). New York: Macmillan Publishing Company.

Buol, S.W., F. D. Hole and R. J. McGracken. 1989. *Soil Genesis and Classification* (3rd ed.). Ames: Iowa State University Press.

Buol, S.W., P. A. Sanchez, R. B. Cate, Jr., and M. A. Granger. 1975. Soil fertility capability classification: a technical soil classification system for fertility management. In: *Soil Management in Tropical America*, ed. E. Bornemisza and A. Alvarado, pp. 126-145. Raleigh, North Carolina: North Carolina State University.

Chinene, V.R.N. 1992. Land evaluation using the FAO framework; an example from Zambia. *Soil Use and Manage*. 8: 130-139.

Enwezor, W. O., E.J. Udo and R,A.Sobulo. 1981. Fertility status and productivity of the ‘acid sands’, pp. 56-73. In: *Acid Sands of Southern Nigeria*, ed E. J. Udo and R. A. Sobulo . SSSN Special Publication, Monograph No.1.

Esu, I.E. 2005. Characterization, Classifications and Management Problems of the Major Soil Orders in Nigeria. 26th Inaugural Lecture, University of Calabar, Calabar, Nigeria.

Food and Agriculture Organisation (FAO) 1976. A Framework for Land Evaluation. FAO Soils Bull.32, FAO, Rome.

FAO. 2006. *Guidelines for Soil Descriptions* (4th ed.). FAO, Rome

FMANR (Federal Ministry of Agriculture and Natural Resources). 1990. *Literature Review on Soil Fertility Investigations in Nigeria*, ed., W. O. Enwezor, A.C. Ochiri, E.E. Opuwaribo and E. J. Udo, pp. 49-100. Ibadan: Bobma Publishers,

Ibia, T. O. and E. J. Udo, 2009. *Guide to Fertiliser Use for Crops in Akwa Ibom State, Nigeria*. Lagos: Sibon Books Limited.

IITA (International Institute of Tropical Agriculture). 1979. *Selected Methods for Soils and Plant Analysis*. IITA Manual Series 1. IITA, Ibadan, Nigeria.

IUSS Working Group WRB. 2007. World Reference Base for Soil Resources 2006, 1st Update 2007. World Soil Resources Reports No. 103, FAO, Rome.

Jungerius, P.D. 1964. The soils of Eastern Nigeria. P*ublication Service Geological du Luxemburg* XIV: 185-198.

Ogunkunle, A.O. 1993. Soil in land suitability evaluation: an example with oil palm in Nigeria. *Soil Use and Manage*. 9:35-40

Ojanuga, A. G., T. A. Okunsami and G. Lekwa (eds). 2003. *Wetland Soils of Nigeria: Status of Knowledge and Potentials*. Monograph No.2, Soil Science Society of Nigeria (SSSN).

Ojanuga, A.G. 2006. Management of fadama soils for food security and poverty alleviation. In: *Management of Fadama Soils for Environmental Quality Food Security and Poverty Alleviation in Nigeria,* ed. S. Idoga, S. A. Ayuba, A Ali, O. O. Agbede and S. O. Ojeniyi, pp.10-15. Makurdi, Nigeria: Soil Science Society of Nigeria, University of Agriculture.

Petters, S. W., E. J. Usoro, E. J. Udo, U. W. Obot, and S. N. Okpon. 1989. Akwa Ibom State. Physical Background, Soils and Land Use and Ecological Problems. Technical Report of the Task Force on Soils and Land Use Survey. Nigeria: Govt. Printer Uyo.

Sanchez, P.A., W. Couto and S. W. Buol 1982. The Fertility Capability Classification System. Interpretation, applicability and modification. *Geoderma* 27: 283-309.

SCS News. 1984. Soil Survey – Nature, Purpose and Uses. *Soil Taxonomy* News 9: 15-17.

Soil Survey Staff. 2010. *Keys to Soil Taxonomy*. Washington, D.C.: USDA – NRCS.

Sys, C. 1985. Land Evaluation. Parts I, II, III. 247p. Publication No.7 of the General Administration of Cooperation Development. Place de Champs de Mars 5, boite 57, 1050 Bruxelles.

Tahal Consultants. 1982. Qua Iboe River Basin Pre-feasibility Study, Vol. 1. Main Report. Cross River Basin Development Authority, Calabar, Nigeria.

Udo, E.J. 2001. Soil Potentials of the Coastal Zone of Akwa Ibom State. Uniuyo Consult Ltd., Uyo, Nigeria.

Udo, E. J., T. O. Ibia, J. A. Ogunwale, A. O. Ano and I. E. Esu. 2009. *Manual of Soil, Plant and Water Analysis.* Lagos, Nigeria: Sibon Books Ltd.

Udo, E.J. and J. A. Ogunwale. 1986. Laboratory Manual for Analysis of Soil, Plant and Water Samples. Department of Agronomy, University of Ibadan, Nigeria.

Udo, E.J. and R. A. Sobulo (eds). 1981. Acid Sands of Southern Nigeria. Special Publication, Monograph No. 1, Soil Science Society of Nigeria (SSSN).

Unyienyin, S. E. 2010. Soil evaluation and agricultural potentials of beach ridge sands in three locations in Akwa Ibom State, Nigeria. M.Sc. Dissertation, Department of Soil Science, Univ. of Uyo, Nigeria. 156p.