Characterization and Suitability Evaluation of Soils over Sandstone for Cashew (*Anacardium occidentale L*) Production in a Nigerian Southern Guinea Savanna

Ofem, K. I[1]., Abua, S.O[1]., Umeugokwe, C.P[2]., Ezeaku, V. I[2]. and Akpan-Idiok, A. U[1]

[1]Department of Soil Science, University of Calabar, Nigeria
[2]Department of Soil Science, University of Nigeria, Nsukka

DOI: 10.29322/IJSRP.10.07.2020.p10342
http://dx.doi.org/10.29322/IJSRP.10.07.2020.p10342

Abstract- The study examined the properties as well as the Taxonomic classification of soils developed on sandstone in the Southern Guinea Savanna of Nigeria. The soils were also evaluated for their suitability for cashew production. The contour map of Bekwarra was obtained in the ArcGIS 10.2.1.3 environment and two profile graphs plotted to represent two toposequences. Six profile pits were then sited. The soils were deep (>100 cm) to weathered rock with argillic B horizons. The surface soils were dark reddish brown (5YR 3/4) to very dark gray (2.5YR 3/1) and gray (7.5YR 5/1). Soil bulk density was < 1.60 Mg/m^3. Amount of clay fluctuated with soil depth while sand fraction dominated the soils. Irrespective of landscape position, the soils were severe to moderately acid in reaction, and low to moderate in organic carbon. The soils were moderate in exchangeable Ca^{2+} and Mg^{2+} and low in K^+ and Na^+. The soils were moderately suitable (S2) and currently not suitable (N1), potentially for cashew production. Pedon 1 was classified as Typic Haplustalf (Haplic Luvisols), pedons 2, 3 and 4 as Typic Paleustalfs (Haplic Luvisols) while pedon 4 was Rhodic Luvisols in the WRBSR system. Soils at the valley bottom were classified as Aquic Udorthents (Hypereutric Gleysols). Site specific conservation farming, combined application of organic and inorganic fertilizers as well as the application of calcite and dolomite at appropriate dosages are advocated. Furthermore, it is pertinent to change land use of the soils at the valley bottom (pedons 5 & 6).

Index Terms- Soil characterization; classification; toposequence; suitability; cashew

I. INTRODUCTION

Land forms in the sub humid tropics are generally characterized by rolling topography and small valleys; soils formed along such slopes often vary in basic properties and classification. Hence, the agricultural land use potentials of soils along different landscape positions also differ. Sustainable agriculture rests on the in-depth study as well as inventorization of soil resources, consequently, inadequate information on the soil resources of any region contributes to the problem of soil degradation as well as food insecurity.

Different rates of weathering of parent materials, the nutrients they contain for plant use and dominant particle size are some ways in which parent materials influence soil formation. Parent materials are important soil forming factor that contribute to the differences in soil properties (Ibangha, 2006; Esu, 2010). However, Akamigbo and Asadu (1982) observed that parent materials have very significant influence on the overlying soil when the soil is formed *in situ*. Sandstone on which the soils under study is formed is medium grained and composed of quartz and clastic in origin, and occurs in the major ecological zones of Nigeria (Ogunwale and Ashaye, 1975). Soils developed on sandstone are shallow, sandy and gravelly, and are generally erodible (Bulktrade, 1989). Such soils in the Niger Delta area and particularly Akwa Ibom State are fragile, acidic and low in native fertility, and are described as marginal by farmers in the area (Udoh *et al*., 2015).

Adequate information on land resources has been identified as a pre-requisite for sustainable land management (Ofem *et al*., 2016), consequently, Esu (2004) advocated detailed study of soil resources through soil characterization and land evaluation. Land suitability evaluation is a simple avenue to combat the many problems linked to land use (Ofem *et al*., 2016). It also helps individual land owners and regional development agencies to make valid national decisions among available land use and site selection options (Esu, 2013; Widiatmaka *et al*., 2014), and makes it even more necessary to know how suitable the land is for Cashew production.

Cashew has an architecture for reclaiming tracts of land to enhance its productivity (Adeigbe *et al*., 2015). Nearly 90 % of the lateral roots of cashew concentrate in the upper 15-45 cm of the soil while its tap root may extend up to a depth of about 5 m (Schoenmaker, 1998). The crop requires deep, well drained and light to medium textured soils (Sys *et al*., 1993). Its young tap root is sensitive to physical soil limitation (Ngatunga *et al*., 2001) and requires optimum pH of 4.5-6.5 (FAO, 1994). However, Sys *et al*. (1993) recommended an optimum pH of 5.5-7.0. Furthermore, organic carbon of over 0.8 %, CEC of over 12.4 cmol/kg and loam textures with a minimum effective soil depth of 40 cm were recommended for productivity above 80 % (Widiatmaka *et al*., 2014). The crop is draught resistant and requires hot conditions, as frost conditions may result in black nuts or rots (Sys *et al*. (1993). Consequently, cashew productivity decreases with higher rainfall.

Economically, cashew nut accounts for 7-8 % of non-oil export earnings in Nigeria with an estimated USD 25-35 million per year (Nugawela & Oroch, 2005). Production increased from 30,000 in 1990 to 836,500 MT in 2012 (FAOSTAT, 2013). Majority of such export quality come from the eastern and western Nigeria (Adeigbe *et al*., 2015). Nigeria was ranked second in the world, next to only Vietnam and first in Africa in 2010, 2011 and 2012 with production estimated at 650000, 813023 and 835500 MT, respectively (Ogunsinan & Lucas, 2008 & FAOSTAT, 2013). Since 2014, cashew has become the second main cash crop in west Africa behind cocoa and ahead of cotton, rubber, palm oil or banana (Nitidae, 2019). In 2018, 250,000 MT was produced in Nigeria from an area of 755,000 ha (Nitidae, 2019).

The agricultural potentials of the soils have not been fully harnessed due to scanty recent research on the soils; hence the adoption of wrong land management methods and land use types by the farmers who are either not exposed to relevant information regarding the soils they intend to cultivate or such information are too cumbersome for their understanding. This has resulted in underutilization and degradation of the soils as they are often not used for what their characteristics match for. It is therefore apt to study the soils in order to bridge the gap in soil resource information and also expand on their agricultural use options through suitability evaluation for cashew production. Although the soils have been adjudged to be low in fertility status (Udoh *et al*., 2015), oil palm, cashew, rice and maize as well as cassava, sorghum and yam have been found to have comparative advantage over other crops. This study is therefore saddled with the responsibility of characterizing and taxonomically classifying the soils based on the criteria of USDA and correlating same with the World Reference Base for Soil Resources System. Suitability evaluation of the land will also be carried out to ascertain its fitness and possible consideration for intensive and commercial production of cashew.

II. MATERIALS AND METHOD

Environment of study area

The study was sited in Bekwarra Local Government Area (LGA) of Northern Cross River State. It lies in the southern guinea savanna of Nigeria with patches of rainforest and located between longitudes 4°21' and 6°45'E, and latitudes 7°15' and 9°28'N. It is bounded to the North by Vandikyia in Benue State and to the East by Obudu cattle ranch. Soils in the area are developed on sedimentary formation which constitutes fine grained sandstone, shales and siltstone with local occurrences of limestone (Bulktrade, 1989). The study area varies between level to nearly level and gently undulating local relief with pronounce hills. Rainfall varies between 1251.4 and 3347.8 mm/annum while range of 22.96-33.75 °C characterizes temperature in the area (Sambo *et al*. 2016). Mean relative humidity was reported as 72.14 % while evaporation rate had mean value of 2.24 mm/day and range of 1.8-2.8 mm/day. The area is dominated by grass species like; *Andropogon spp*., *Imperata cylindrical*, *Combretum spp*., *Panicum maximum* and tree species like *Elaeis guineensis*, *Bukrea Africana*, *Gmelina aborea*, and *Anacardium occidentale*.

Field studies

The contour map of Bekwarra was obtained in the ArcGIS 10.2.1.3 environment. Considering the distribution of elevations on the contours, topo-positions were identified and two profile graphs plotted to represent two toposequences. Each toposequence was located in Anyikang and Ibiaragiri (Fig. 1). These are major agrarian communities in Bekwarra LGA. These locations have major advantages for the production of cashew in the area. Upon field reconnaissance verification, point locations representing soil profile pits were obtained with the aid of the GPS device. Soil profile pits were then sited in the summit, middle slope and valley bottom positions of each toposequence to represent the soils. Furthermore, pedons were dug and described according to the requirements of Soil Survey Staff (2012). Soil samples were obtained from pedogenic horizons, labeled and transported to the laboratory for analysis. Samples meant for bulk density determination were collected with the aid of cylindrical cores that were drilled vertically downwards. The core samples were oven dried at 105 °C until constant weight was obtained.

Laboratory studies

Soil samples were air dried under laboratory conditions, grinded and sieved through a 2 mm mesh. The fine earth fraction (< 2 mm) was used for various laboratory analyses. Particle size analysis of was done by the Bouyoucos hydrometer method using sodium hexametaphosphate as the dispersant (Gee and Bauder, 1986) while bulk density (Bd) was determined by undisturbed core cylinder (Blake, 1965) and particle density (Pd) was determined by the use of a pycnometer (Bowles, 1992). Consequently,total porosity (Tp) was determined from the expression: $TP = (1 - Bd/Pd) \times 100$. Soil pH was determined in a soil to water ratio of 1:1 using a glass electrode pH meter while soil organic carbon was obtained by the Walkley and Black wet oxidation method and total N was determined by the macro Kjeldahl digestion method (Udo *et al*., 2009). Bray 1 solution was used as extractant in the colorimetric determination of available P while exchangeable bases were extracted with 1 *N* neutral NH_4OAc. Exchangeable Ca and Mg were thereafter obtained by the Versenate EDTA titration method while K and Na were determined with the aid of a flame photometer (Udo *et al*., 2009). Cation exchange capacity was determined in neutral NH_4OAc as outlined by Udo *et al*. (2009) while base saturation was obtained by expressing the sum of exchangeable bases as a percentage of the CEC by NH_4OAc at 7.0.

Land suitability evaluation procedures

Land suitability for cashew production was according to the requirements of Sys *et al*. (1993) (Table 4). The pedons were placed in suitability classes by comparing the data obtained in the study area (Table 3) to cashew requirement (Table 1). The most limiting factor was used to determine the overall suitability ratings in accordance with Liebig's law of minimum.

For the parametric (square root method) method, each limiting characteristic was rated as shown in Table 1. The potential and current indices of productivity (IP) for each pedon were computed using the equation:

IP = A $\sqrt{B}/100 * C/100 \ldots. E/100$; Where: A = Overall lowest characteristic rating; B, C … E = The lowest characteristic rating for each land quality group.

Since there are often strong correlations within a land quality group, only one member with the least rating in each of climate (c), wetness (w), physical soil characteristics (s), soil fertility (f) and available nutrients (a) were used to calculate the index of productivity; current and potential productivity. In potential productivity, properties (organic C, total N and available P) that are easily altered by soil management procedures were masked.

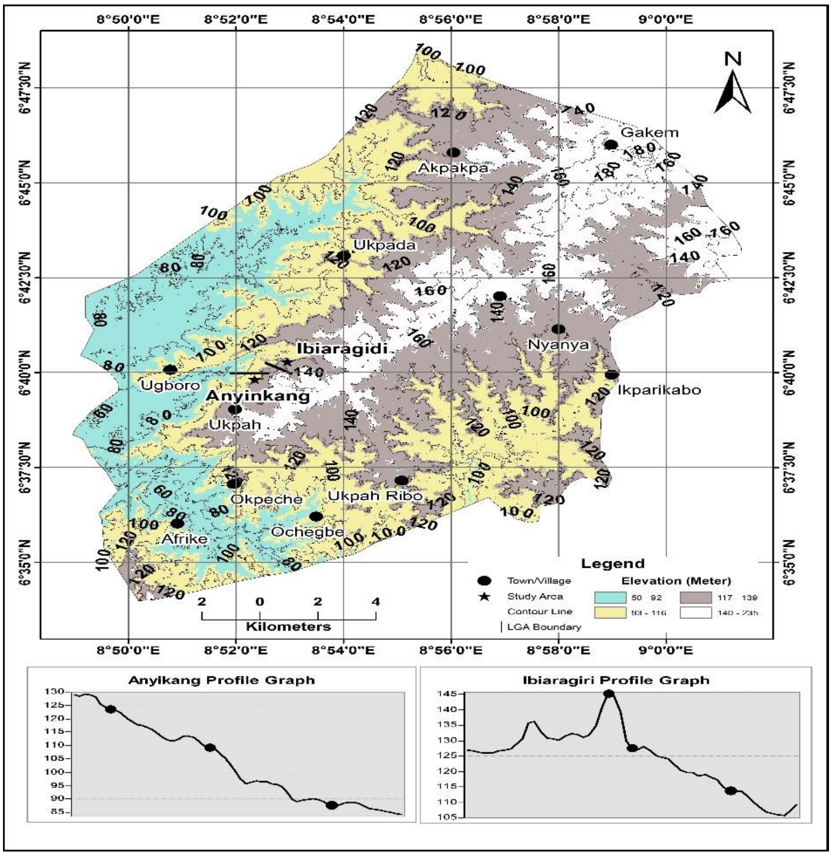

Fig. 1: contour and location map of Bekwarra with profile points

Table 1: Land requirement for Oil palm production indicating; Class, degree of limitation and rating scale

Land Characteristics	S1 0	 1	S2 2	S3 3	N1	N2 4
Rating scale	100-95	95-85	85-60	60-40	40-25	25-0
Climate (c)						
MAR(mm/yr)	1800-1600	1600-1200	1200-800	800-500	-	<500
	1800-2000	2000-3000	3000-3800	>3800	-	-
MAT (°C)	>25	25-22	22-20	<20	-	-
Wetness (w)						
Flooding	Fo (No flooding)	-	-	-	- -	F1+ Severe; Every year
Drainage	Good, moderate	Good; moderate	Imperfect + Fluctuating H_2O	Imperfect + Permanent high	Poor but drainable	Poor; not drainable
Physical soil characteristics (s)						
Texture	C, SiC, SiCL, CL, SiL, SC	C,L,LfS,SCL,SL	fS, LCS	S, CS	-	SiC
Soil depth (cm)	>150	150-100	100-50	50-25	-	<25
Soil fertility characteristics (f)						
*CEC (cmol/kg)	>12.4	8.5-12.4	2.6-8.5	<2.6	-	-
BS (%)	>35	35-20	<20	-	-	-
pH (H_2O)	6.0-5.5, 6.0-7.0	5.5-5.2, 7.0-7.5	5.2-4.8, 7.5-8.0	4.8-4.5, 8.0-8.5	<4.5	>8.5
Org. C (%)	>1.5	1.5-0.8	<0.8	-	-	-
Available nutrients (a)						
*Total N (%)	>0.07	0.05-0.07	0.03-0.05	<0.03	-	-
*AvailableP(ppm)	>40	11-40	1-11	<1.0	-	-
*Exch.K(cmol/kg)	>0.37	0.27-0.37	0.10-0.27	<0.10	-	-

Source: Sys *et al*. (1993); *Widiatmaka *et al*. (2014)

III. RESULTS AND DISCUSSION

Soil morphological properties

Dark reddish brown (5YR 3/4, 2.5YR 2.5/4), very dark greyish brown (10YR 3/2) to dark brown (10YR 3/3), and very dark gray (2.5YR 3/1) overlaid dark red (2.5YR 3/6) to red (2.5YR 4/8), dark brown (7.5YR 3/3) and red (2.5YR 4/6), and gray (7.5YR 5/1) colours in the crest, middle slope and valley bottom, respectively (Tables 2a,b,c). Reddish soil colour in the crest and middle slope is indicative of the presence of oxides and oxyhydroxides of iron and aluminum, and further suggests soil maturity or well-drained condition. Souza *et al*. (2019) attributed such colours to the presence of goethite and hematite.

Table 2a: Morphological properties of the soils

Horizon	Depth (cm)	Soil Colour (moist)	Mottling	Texture	Structure	Consistence	Boundary	Other characteristics
Crestal soils								
Pedon 1 (N06°40'500", E 008°52'054", 120m ASL)								
Ap	0 – 33	2.5YR 2.5/4	-	gsl	Wfgbk	wss; mvfr	cs	Medium common pores; many coarse roots; few iron nodules; quartz mineral; many ants and termites.
Bt	33 – 72	2.5YR 4/8	-	scl	mfmsbk	wns; mvfr	cw	Common moderate clay and iron cutans on pores; common many fine medium roots; iron nodules; many quartz; few ants and termites.
Cr1	72 – 133	2.5YR 4/8	-	sl	mmsbk	wns; mvfr	gs	Few thin cutans pores; few common coarse roots; iron nodules; many quartz.
Cr2	133 – 200	2.5YR 4/8	-	sl	wmsbk	wns; mvfr	-	Few fine pores; few medium roots; few iron nodules and many quartz.
Pedon 2 (N06°40'932", E 008°53'663", 145 m ASL)								
Ap	0 – 28	5YR 3/4	-	scl	2m sbk	wss; mfr	cs	Very few fine thin clay cutans pores; many common pores; common medium roots; ants and termites.
Bt	28 – 105	2.5YR 4/8	-	sc	2m sbk	wss; mf	cw	Few thin clay cutans pores; common medium roots; termites and ants; rock outcrop.
Cr1	105 – 147	2.5YR 3/6	-	sc	wm sbk	wss; mvfr	gs	Very few thin clay cutans on pores; few very fine pores; few very fine roots; ants, termites.
Cr2	147 – 200	2.5YR 3/6	-	gsc	wm sbk	ws; ,mvfr	-	Few moderate clays and iron cutans on ped faces; iron nodules; quartz; oxides of iron.

On the other hand, dark and brown colours common in the surface soils are due to the presence of decomposed organic matter. This result is similar to those of Bulktrade (1989) in the study area and Ahukaemere *et al*. (2013) on similar soils elsewhere. Furthermore, gray colours obtained in the valley bottom soils indicates loss of oxides of Fe and Al, as well as wetting. Similar colours were obtained by Ukut *et al*. (2014).

Irrespective of the landscape positions, textural class in the surface soils was mainly loam with variable sand content giving rise to sandy loam and sandy clay loam. The subsurface soils seemed to have similar or finer textures across the landscapes. This suggests greater vertical than lateral movement of fine particles. Such textures are typical of sandstone soils and are responsible for the well-drained soil condition. Similar textures were obtained by Bulktrade (1989) while Laffan *et al.* (1998) obtained sandy loam, loamy sand and clay textures in the sandstone soils of Northern Tasmania, New Zealand.

Soil consistence in the crest was slightly sticky when wet, and friable to very friable in moist condition for the surface soils while the underlying soils were more sticky (Tables 2a,b,c). However, consistence under moist condition ranged from friable to very friable and firm in the middle slope and valley bottom (Tables 2b,c). Ahukaemere *et al.* (2013) had consistence varying from friable to very firm in the surface soils and very friable to firm in the subsurface soils. Plant roots, ants and termites beyond 122 cm indicate the absence of physical impediments, as well as the availability of water and nutrients at such depths. Ants, worms and termites encourage decomposition and soil mixing. Clay cutans were found in almost all the subsurface horizons of the crest and middle slope soils (Tables 2a,b), and indicates soil maturity.

Table 2b: Morphological properties of soils at the middle slope

Horizon	Depth (cm)	Soil Colour (moist)	Mottling	Texture	Structure	Consistence	Boundary	Other characteristics
Middle slope soils								
Pedon 3 (N 06°40'324", E 08°51'871", 105 m ASL								
Ap	0 – 15	10YR 3/2	-	sl	wm gbk	ws; mvfr	cs	Many common pores; many few roots; many quartz; many ants.
Bt1	15 – 43	5YR 4/6	-	scl	2m sbk	wss; mvfr	gs	Few thin clay cutans on ped faces; quartz; very few ants.
Bt2	43 – 97	5YR 4/6	-	sc	2mc sbk	wss; mvfr	gs	Common thin clay cutans on ped faces; common medium coarse roots; quartz; very few ants.
Cr1	97-137	10YR 4/6	10YR 6/6	scl	1mc sbk	wss; mvfr	cw	Common moderate iron clay cutans on ped faces; common very few pores; few fine roots.
Cr2	137-200	2.5YR 3/6	10YR 6/4	scl	mcgbk	wss; mvfr		Moderate clay cutans on ped faces; few very fine pores; quartz.
Pedon 4 (N 06°40'850", E 08°53'768", 135 m ASL								
Ap	0 – 16	10YR 3/3	-	gsl	wmgbk	wns; mfr	cs	Many common pores; many coarse roots; quartz;few ants. common few roots; ants
Bt	16 – 69	7.5YR 3/3	-	gsc	wm gbk	ws; mfr	gw	Many medium pores; common medium roots; iron nodules; quartz; very few ants;out crop of sandstone rock.
BC	69 – 122	5YR 4/6	-	gsc	wm sbk	wss; mfr	dw	Common moderate pores;clay cutans; few common pores; few fine roots; iron nodules; quartz; very few ants.
Cr	122 – 200	2.5YR 4/6	-	scl	2m sbk	wss; ,mfi	-	Common thick clay cutans on ped faces; few medium pores; quartz.

Table 2c: Morphological properties of soils at the valley bottom

Horizon	Depth (cm)	Soil Colour (moist)	Mottling	Texture	Structure	Consistence	Boundary	Other characteristics
Valley bottom soils								
Pedon 5 (N 06°40'197", E 08°51'873", 88 m ASL								
Ap	0 – 20	2.5 YR 3/1	7.5YR 4/4	Scl	2mg	wss; mvfr	cs	Few fine roots; worms and ants.
Cg1	20 - 86	2.5 YR 5/6	2.5YR 4/1	scl	2msbk	ws; mf	gs	Very few thin clay cutans on ped faces; very few pores.
Cg2	86 – 130	2.5 YR 5/1	5YR 4/6	c	2msbk	wss,mf	-	Few thin clay cutans on ped faces; fine very few pores.
Pedon 6 (N 06°40'758", E 08°53'737", 113 m ASL								
Ap	0 – 12	7.5YR 5/1	-	Sl	wfg	wss; mvfr	cs	Common medium pores; many medium roots; ants and cricket.
Cg	12 – 50	7.5YR 5/2	2.5YR 4/1	Scl	wfg	wss; mfr	-	Common very few pores; many medium roots; ants. medium pores; common medium roots;ants.

Foot note: Texture: gr = gravel, Co = cobbles, L = loam, S = sand, C = clay; Structure: 1,2,3 = weak, moderate and strong, f,m.c = fine, medium and coarse; gr. abk and sbk = granular, angular blocky structure and sub-angular blocky structure; Consistence: w = wet, m = moist, s = slightly sticky, fr = friable, fi = firm, v = very; Boundary: cs = clear smooth, ds = diffuse smooth, gs = gradual smooth, cw = clear wavy, dw = diffuse wavy, gw = gradual wavy; Asl: Above sea level

The abundance and size of soil pores seemed to decrease with soil depth and down the slope, especially in the poorly drained valley bottom. The porous nature of soils in the crest and middle slope may have been responsible for its well-drained nature giving rise to bright colours.

Soil physical properties

Physical properties of the soils are presented in Tables 3a,b,c. Particle size distribution of the soils indicates that sand content exceeded 500 g/kg in the surface soils with comparatively lower values in the subsurface soils. Also, values at the valley bottom appeared lower and suggest limited lateral movement of sand grains. Souza *et al.* (2019) obtained > 741 g/kg of sand in the soils overlying Piaui sandstone derived soils in Brazil

High values of sand in the crest and middle slope affirms that the soils were developed *in situ* while the gently undulating landscape limited the movement of sand grains downslope. Such values of sand are likely to increase the infiltration rate, percolation and leaching, and reduce the availability of nutrients in the soil exchange complex. Similar results were obtained by Lawal *et al.* (2012) in Muma while higher values were obtained by Ahukaemere *et al.* (2013) and Udoh (2015) in the Southeastern and Niger Delta regions of Nigeria. However, Naganori *et al.* (1984) obtained lower values in Japan.

Silt fraction was less than 290 g/kg in the entire soils and appeared higher in the valley bottom than other landscape positions. This suggests the ease with which finer particles are moved compared to sand. The finding agrees with the work of Naganori *et al.* (1984), Lawal *et al.* (2012) and Ahukaemere *et al.* (2013) while Udoh (2015) obtained values lower than seen in the present study.

Clay fraction increased vertically downwards and downslope resulting in higher values in the B horizons and the valley bottom, respectively (Tables 3a,b,c). A further indication that clay particle sizes were easily moved compared to sand sizes.

Table 3a: Physical properties of the soils in the crest

Horizon	Depth	Sand	Silt	Clay	Text.	Bd	Pd	TP	WC	Air filled
	cm	←	g/kg →			←	Mg/m^3 →	←	%	→
Pedon 1										
Ap	0-33	740	140	120	Sl	1.56	2.5	37.6	4.7	32.86
Bt	33-72	590	100	310	Scl	1.52	2.2	30.9	6.1	24.8
Cr1	72-133	620	190	190	Sl	1.43	2.3	37.8	7.1	30.7
Cr2	133-195	790	90	120	Sl	1.54	2.6	40.7	8.2	32.5
Pedon 2										
Ap	0-28	580	180	240	Scl	1.37	2.4	42.9	5.3	37.6
Bt	28-105	490	100	410	Sc	1.26	2.1	40	6.8	33.2
Cr1	105-147	460	160	380	Sc	1.48	2.3	32.7	8.7	24
Cr2	147-200	490	130	380	Sc	1.63	2.2	23.6	9.7	13.9
Surface Mean		660	160	180	Sl	1.47	2.5	40.3	5	35.2
Surface Range		580-740	140-180	120-240		1.37-1.56	2.4-2.50	37.6-42.9	4.74-5.29	32.86-37.6
Subsurface Mean		570	128	300	Scl	1.5	2.3	28	8	26.52
Subsurface Range		460-790	90-190	120-410		1.26-1.63	2.1-2.6	23.6-40.7	6.10-9.72	13.9-33.2

Table 3b: Physical properties of the soils in the middle slope

Horizon	Depth	Sand	Silt	Clay	Text.	Bd	Pd	TP	WC	Air filled
	cm	←	g/kg →			←	Mg/m^3 →		←	% →
Pedon3:										
Ap	0-15	720	220	60	Sl	1.4	2.2	36.4	5.26	31.1
Bt1	15-43	610	130	260	Scl	1.5	2.6	42.3	5.84	36.5
Bt2	43-97	580	40	380	Sc	1.65	2.6	36.5	6.97	29.5
Cr1	97-137	540	130	330	Scl	1.48	2.3	35.7	7.94	27.8
Cr2	137-200	540	150	310	Scl	1.28	2.2	41.8	7.02	34.9
pedon 4:										
Ap	0-16	680	200	120	Sl	1.42	2.1	32.4	4.32	28.1
Bt	16-69	560	80	360	Sc	1.29	2.8	53.9	6.56	47.3
BC	69-122	490	160	350	Sc	1.35	2.3	41.3	6.93	34.4
Cr	122-200	570	170	260	Scl	1.49	2.3	40.4	8.48	31.9
Surface Mean		700	210	90	Sl	1.41	2.15	34.4	4.79	29.6
Surface Range		680-720	200-220	60-120		1.4-1.42	2.1-2.2	32.4-36.4	4.32-5.26	28.1-31.1
Subsurface Mean		558	123	321	Scl	1.43	2.44	47.7	7.11	34.6
Subsurface Range		490-610	40-170	260-380		1.29-1.65	2.2-2.8	35.7-53.9	5.84-8.48	27.8-47.3

Table 3c: Physical properties of the soils in the valley bottom

Horizon	Depth	Sand	Silt	Clay	Text.	Bd	Pd	TP	WC	Air filled
	cm	←	g/kg	→		←	Mg/m^3 →	←	%	→
Pedon 5										
Ap	0-20	520	260	220	Scl	1.39	2.3	39.6	12.6	27
Cg1	20-86	540	180	280	Scl	1.51	2.4	37.1	14.1	23
Cg2	86-130	390	100	510	C	1.45	2.4	39.6	15.1	24.5
Pedon 6										
Ap	0-12	620	290	90	Sl	1.09	2.3	52.6	21.5	31.1
Cg	12.0-50	570	210	220	Scl	1.4	2.3	39.3	24.4	14.9
Surface Mean		570	275	155	Sl	1.24	2.3	46.1	17.1	29.1
Surface Range		520-620	260-290	90-220		1.09-1.39	-	39.6-52.6	12.6-21.5	27-31.1
Subsurface Mean		500	163	337		1.4	2.4	38.7	17.9	20.8
Subsurface Range		390-570	100-210	220-510		1.24-1.51	2.3-2.4	37.1-46.1	14.1-24.4	14-24.5

Foot note: BD= Bulk density, Pd= particle density, TP= Total porosity, WC= Water content

Similar findings were reported by Souza *et al*. (2019) for the sandstone soils of Piaui, Brazil. Increasing clay content with depth, particularly in the B horizons is indicative of lessivation. Values obtained in this study are higher than those of Ahukaemere *et al*. (2013) and Udoh (2015) and corroborates those of Lawal *et al*. (2012).

The coefficient of variation (CV) of silt and clay down the toposequences were 22 and 27 %, respectively for the surface soils, while sand had very low values. This suggests that surficial erosion or lateral movement encourages mainly fine particles; clay and silt.

The bulk density values ranged between 1.09 in the valley bottom and 1.65 Mg/m^3 in the middle slope of the soils (Tables 3a,b,c). Irrespective of the landscape positions, the surface mean values were within 1.1 – 1.4 Mg/m^3 suggested for cultivated loams (Donahue *et al.*, 1983), but were less than 1.60 Mg/m^3. This indicates that air and water movement in the soils are optimum for plant growth (Esu, 2010). Also, particle density was slightly less than 2.65 Mg/m^3 (Table 2) recommended for mineral soils in the tropics (Blake, 1965). Such values may indicate lower amounts of oxides of Fe and Mn in the soils. Bulk and particle densities had very low variability with landscape position (CV < 7 %).

Forms of porosity and values obtained are presented in Tables 3a,b,c. Mean values of total porosity were less than 50 % while air-filled porosity (macro porosity) exceeded 25 % and volumetric water content (micro porosity) was quit low for the surface and subsurface soils of all the landscape positions. However, very high CV of water content (> 40 %) between landscape positions irrespective of soil depth, indicates variation in soil drainage with depth and landscape position and agrees with the concept of a catena. Total porosity values were within the range of values obtained by Ahukaemere *et al.* (2013) in the false bedded sandstone derived soils of Southeastern Nigeria; however, Ahukaemere and Akpan (2012) had higher values of 26.76 – 43.02 % in soils of Amasiri in Ebonyi State, Nigeria.

Chemical properties of the soils

Results of chemical properties of the soils are presented in Table 4. Mean soil pH values were comparatively higher in the subsurface soils (Table 4), and rated as severely and moderately acid for the entire soils (Holland *et al.*, 1989). Low pH in sandstone derived soils is attributed to low soil base status (Souza *et al*., 2019). This indicates that significant amounts of exchangeable Al^{3+} and H$^+$ may be present to significantly affect plant growth (Esu, 2010). The pH seems to have been more influenced by exchangeable H$^+$ as its values were higher than exchangeable Al^{3+} in over 95 % of the horizons (Table 4). Consequently, exchangeable Al^{3+} was generally less than 2.1 cmol/kg as recommended by Holland *et al.* (1989) for most arable crops. Such values are not likely to be toxic to plant roots as to affect its proliferation. Sandstone derived soils seem to vary in pH with location (Ahukaemere *et al.*, 2013; Bulktrade, 1989). However, the pH values obtained by Ukut *et al.* (2014) in similar soils elsewhere were similar to those obtained in the present study. Very low CV for soil pH indicates that it is poorly influenced by the toposequences while exchangeable acidity had values that were > 20 %.

Soil organic carbon was rated low in the crest and valley bottom, but moderate in the middle slope (Table 4) (Holland *et al.*, 1989). The low soil organic carbon may be attributed to organic matter mineralization, loss to leaching, and bush burning. These values agree with those of Bulktrade (1989) in the Bekwarra area and vary with those of Ogunwale and Ashaye (1975). The CV of organic C was greater than 20 % and indicates variability with landscape position imposed by land use. Total N had similar trend as organic C and was rated as low to very low (Table 4) in the entire soils (Holland *et al.*, 1989). According to Eshett (1985), low nitrogen in an area is attributed to crop removal and rapid mineralization of organic matter. Laffan *et al.* (1998) obtained similar results in Northern Tasmania, New Zealand.

The C/N values were less than the separating index of 25 (Paul and Clark, 1989) and 20 (Agbede, 2009) (Table 4), and were rated low. This ratio will encourage high level of microbial activity, increased decomposition of organic matter and corresponding release of nutrient elements into the soil solution for plant root uptake (Akpan-Idiok and Ofem, 2014). Available P was rated low (Holland *et al.* 1989) in the entire soils, however, the middle slope soils appeared to be comparatively higher than other landscape positions (Table 4). The surface soils had higher variation (CV) with landscape positions than the subsurface soils. Surface soils are most often manipulated than subsurface soils. This may be due to the influence of agricultural activities such as tillage, manure/fertilizer application, and fecal manure/fertilizer application, and

Table 4: Chemical properties of the soils in the crest

Horizon	Depth	pH	O C	T.N	C/N	Av.P	Ca	Mg	K	Na	Al^{3+}	H^+	EA	CEC	CEC/Clay	BS	Ca/Mg	Mg/K
	cm	H_2O	←	g/kg →		mg/kg	←				cmol/kg		→			%		
Crest																		
Pedon 1: Typic Haplustalf (Haplic Acrisols)																		
Ap	0-33	5.5	0.64	0.05	12.8	11	4	1	0.1	0.07	0.8	0.4	1.2	15	1.25	81	4	10
Bt	33-72	6	0.56	0.04	14	6	7.8	3	0.12	0.09	0.8	0.4	1.2	15	0.48	90	2.6	25
Cr1	72-33	6	0.09	0.01	9	7	8	3.6	0.12	0.08	0.8	0.4	1.2	16	0.84	91	2.22	30
Cr2	133-195	5.9	0.09	0.01	9	3.12	6.5	1.5	0.11	0.09	0	1.2	1.2	15	1.25	87	4.33	13.64
Pedon 2: Typic Paleustalf (Haplic Acrisols)																		
Ap	0-28	5	0.84	0.07	12	1.75	4.8	0.8	0.13	0.1	0.08	0.08	0.16	25	1.04	78	6	6.15
Bt	28-105	5.5	0.38	0.02	19	1.25	5.8	1.4	0.1	0.09	1.2	1.2	2.4	15	0.37	75	4.14	12.73
Cr1	105-147	5.8	0.38	0.02	19	0.37	6	1.4	0.11	0.08	1.2	0.8	2	26.6	0.68	79	4.29	12.73
Cr2	147-200	6	0.14	0.01	14	0.3	8.8	2.4	0.12	0.08	1.6	0.4	2	25	0.66	85	3.67	20
Surface mean		5.25	0.74	0.06	12.4	6.4	4.4	0.9	0.12	0.07	0.44	0.6	0.68	20	1.15	79.5	5	8.08
surface range		5.0-5.5	0.64-0.84	0.05-0.07	12.0-12.8	1.75-11.0	4.0-4.8	0.8-1.0	0.10-0.13	0.07-0.10	0-0.80	0.40-0.80	0.16-1.2	15.0-25	1.04-1.25	78.0-81.0	4.00-6.00	6.15-10
Subsurface mean		5.9	0.27	0.02	14	3	7.15	2.22	0.11	0.06	0.69	0.73	1.67	18.67	0.71	84.5	3.21	16.9
subsurface range		5.5-6	0.09-0.56	0.01-0.04	9.0-19	0.30-7.00	5.8-8.8	1.4-3.6	0.10-0.12	0.08-0.09	0-0.16	0.40-0.12	1.20-2.4	15.0-26	0.37-0.84	75.0-91.0	2.22-4.33	12.73-30
middle slope																		
pedon 3: Typic Paleustalf (Haplic Acrisols)																		
Ap	0-15	5.2	0.84	0.07	12	9.25	7.6	1.8	0.12	0.09	0	0.8	0.8	14	2.33	92	4.22	15
Bt1	15-43	5	0.32	0.02	19	1	5.2	0.8	0.1	0.07	0.24	2.56	2.8	30	1.15	69	6.5	8
Bt2	43-97	5.8	0.32	0.02	19	5.25	5	0.6	0.1	0.07	2.4	0.4	2.8	26	0.68	66	8.39	6
Cr1	97-137	5.8	0.08	0.01	8	1.25	5.6	0.8	0.11	0.09	1.6	1.2	2.8	18	0.55	70	7	7.27
Cr2	137-200	5.8	0.16	0.01	16	1.25	4.2	1.4	0.1	0.08	1.2	1.6	2.8	27	0.87	67	3	14
pedon 4: Typic Paleustalf (Rhodic Luvisols																		
Ap	0-16	5.3	1.54	0.13	11.8	6.12	6	1	0.11	0.08	0.8	0.4	1.2	14	1.17	86	6	9.09
Bt	16-69	5	0.8	0.07	11.4	2.5	5	0.8	0.12	0.09	1.2	1.6	2.8	26	0.72	68	6.25	6.67
BC	69-122	5.1	0.16	0.01	16	1.12	5.6	1	0.11	0.08	0.8	1.2	2	17	0.49	77	5.6	9.09
Cr	122-200	5.2	0.1	0.1	10	0.5	5.8	1.2	0.12	0.1	0.8	0.4	1.2	18	0.69	87	4.83	10
Surface mean		5.25	1.19	0.1	11.9	7.67	6.8	1.4	0.12	0.09	0.4	0.6	1	14	1.75	89	5.11	14.5
surface range		5.20-5.30	0.84-1.54	0.07-0.13	11.8-12.0	6.12-9.25	6.0-7.6	1.0-1.8	0.11-0.12	0.08-0.09	0.00-0.08	0.40-0.80	0.8-1.2	0.0-14.0	1.17-2.33	86.00-92,00	4.22-6.00	9.09-15.00
Subsurface mean		5.39	0.17	0.02	14.2	1.84	5.2	0.94	0.11	0.08	1.18	1.28	2.46	23.1	0.74	72	5.93	8.02
subsurface range		5.0-5.8	0.08-0.32	0.01-0.07	8.0-19.0	0.50-5.25	5.0-5.8	0.6-1.4	0.10-0.12	0.07-0.10	0.24-1.60	0.40-2.56	1.20-2.8	17.0-30.0	0.49-0.87	66.00-87.00	3.00-8.39	6.00-10.00

Footnote: OC (Organic carbon); T.N (Total nitrogen); Av.P (available phosphorus); EA (Exchangeable acidity); CEC (cation exchange capacity); BS (Base saturation) fecal and leaf dropping as well as surficial erosion.

The soils exchange complex was dominated by exchangeable Ca^{2+} and Mg^{2+} with values that were rated as moderate (Holland *et al*., 1989). Souza *et al*. (2019) also reported the dominance of Ca and Mg ions in sandstone derived soils in Piaui, Brazil. Exchangeable Ca had a range of 4 – 8.8 cmol/kg while exchangeable Mg ranged from 0.8 to 3.6 cmol/kg in the entire soils (Table 4). Values of exchangeable K^+ and Na^+ were rated low as they were less than 0.13 and 0.10 cmol/kg (Table 4), respectively (Holland *et al*., 1989). Souza *et al.* (2019) reported very low values for exchangeable K in

Table 4 Contd.

Horizon	Depth	pH	O C	T.N	C/N	Av.P	Ca	Mg	K	Na	Al^{3+}	H^+	EA	CEC	CEC/Clay	BS	Ca/Mg	Mg/K
	cm		← g/kg →			mg/kg	←				cmol/kg				→	%		
valley bottom																		
pedon 5: Aquic Udorthents (Hypereutric Gleysols)																		
Ap	0-20	5.2	0.86	0.07	12.28	1.12	5.4	0.8	0.1	0.08	0.8	0.4	1.2	32	1.45	84	6.75	8
Cg1	20-86	5.7	0.36	0.02	18	5.5	6.8	1.4	0.11	0.07	0	1.2	1.2	26	0.93	87	4.86	12.73
Cg2	86-130	5	0.16	0.01	16	3.12	5.4	1.6	0.1	0.07	0	0.4	0.4	50	0.98	94	3.38	16
pedon 6: Aquic Udorthents (Hypereutric Gleysols)																		
Ap	0-12	5.4	0.94	0.08	11.75	2.37	5.6	1	0.11	0.08	0.8	0.4	1.2	15	1.67	85	5.6	9.09
Cg	12-50	5	0.72	0.06	12	0.87	5	1	0.1	0.08	2	2.8	4.8	14	0.64	62	5	10
Surface mean		5.3	0.9	0.075	12.05	1.75	5.5	0.9	0.11	0.08	0.8	0.4	1.2	23.5	1.56	84.5	6.18	8.55
surface range		5.20-5.40	0.86-0.94	0.07-0.08	11.8-12.3	1.12-2.37	5.4-5.6	0.80-1.00	0.10-0.11	0.00-0.08	0.00-0.80	0.00-0.40	0-1.20	15.0-32	1.45-1.67	84.0-85.0	5.60-6.75	8.00-9.09
Subsurface mean		5.23	0.41	0.03	15.33	3.16	5.73	1.33	0.1	0.07	0.67	1.47	2.13	30	0.85	81	4.41	12.9
subsurface range		5.00-5.70	0.16-0.72	0.01-0.06	12.0-18.0	0.87-5.50	5.0-6.8	1.00-1.60	0.10-0.11	0.07-0.08	0.00-2.00	0.40-2.80	0.40-4.8	14.0-50	0.64-0.98	62.0-94.0	3.38-5.00	10.0-12.73

Footnote: OC (Organic carbon); T.N (Total nitrogen); Av.P (available phosphorus); EA (Exchangeable acidity); CEC (cation exchange capacity); BS (Base saturation) sandstone derived soils with values approaching zero. These results are similar to those of Bulktrade (1989) in the study area. The exchangeable bases may have been weakly held in the exchange complex and then leached from the porous and sand dominated soils of the area. Soils limiting in K^+ with coarse textures may not be highly suitable for Oil palm cultivation (Ofem *et al*., 2016), hence the evaluation of same soils for cashew production.

The exchangeable bases had CV values in the order Mg > Ca > Na > K, with Mg being the most variable down the toposequences.

Cation exchange capacity by NH_4OAc at pH 7.0 in the soils had ranges of 14-23.5 and 18.67-30.0 cmol/kg in the surface and subsurface soils (Table 4), respectively. These values are moderate to high (Holland *et al*., 1989). Lower values (<8.8 $cmol_c$/kg) of CEC were reported by Souza *et al*. (2019). They further attributed the values to low clay content. Higher subsurface values indicate that clay may have been more responsible for the soils exchange capacity than organic matter. The soils are likely to encourage plants nutrients uptake and increase crop yield. Bulktrade (1989) obtained similar results in the study area while Udoh (2015) obtained lower values for similar soils elsewhere. The CV of CEC7 in the surface soils was > 20 % and indicates higher variability in the surface soils of the toposequences.

Base saturation (BS) values ranged between 66 and 92 % in the middle slope and crest and 14 - 50 % in the valley bottom (Table 4). Such values are high to very high (Holland *et al*., 1989) and indicate that the basic cations are in readily available forms for plant root uptake and correlates with the low values obtained for exchangeable aluminum which was within permissible levels. Similar values were obtained by Bulktrade (1989) and Udoh (2015) for sandstone soils in Bekwarra and Niger Delta region of Nigeria, while Naganori *et al.* (1984) obtained very low to moderate base saturation for the shattered sandstone soils in Southeast, Nigeria. The CV of BS down the toposequences was less than 7 % and described as low.

The Ca-Mg ratio in the soils was either within the range of 3:1 to 5:1 or slightly higher than recommended for productive soils (Landon, 1991), an indication that the interaction between Ca and Mg is appropriate for the growth of crops. Though with moderate levels of Mg and low K, the ratios of the cations were high when compared to the critical level of 1:2 for productive soils (Landon, 1991). This indicates that the interaction between Mg and K in the soils is high enough to support the growth of crops. Mg in the form of Mg^{2+} is more likely to be available to crop plants in the soil relative to K (Akpan-Idiok and Ofem, 2014).

Soil classification

Pedons in the crest and middle slope had high base saturation (NH4OAc pH 7) below the upper boundary of the argillic B horizons with values greater than 50 % as well as Ochric epipedons. The soils qualified as Alfisols. Ustic soil moisture regime qualified them as Ustalfs. Values obtained for CEC/clay in pedon 1 were also greater than 16 cmol/kg in all sub horizons with percent decrease in clay of > 20 % from horizons with maximum clay content. The soil qualified as Haplustalf. However, pedons 2 (crest), 3 and 4 (middle slope) had no densic, lithic or paralithic contacts within 150 cm of the soil surface. Also, with increasing depth the soils do not have clay decrease of 20 % or more from the maximum clay content while chroma of 5 or more was obtained with Hue of 7.5YR and 10YR in the argillic horizon of pedon 4 and Cr1 horizon of pedon 3 respectively. Pedons 2, 3 (Haplic Acrisols) and 4 (Rhodic Luvisols) qualified as Paleustalfs in the greatgroup and as Typic Paleustalf at the subgroup category while pedon 1 (crest) qualified as Typic Haplustalf (Haplic Acrisols).

Valley bottom soils were formed over alluvium, shallow to water table and without pedogenic horizons except Ochric epipedons. They qualified as Entisols; however, the soils fail to meet the criteria of other suborders in Entisols and are classified as Orthents and as Udorthents in the great group category. Consequently, the soils have in all horizons but one within 100 cm of the mineral soil surface, chroma of 2 or less and also aquic conditions for some time of normal years. The soils in the valley bottom qualified as Aquic Udorthents (Hypereutric Gleysols) at the suborder category.

Land evaluation for cashew production

Climate, wetness, physical soil properties as well as fertility qualities were optimum or near optimum for cashew production except limitations occasioned by organic C and available nutrients (a). However, poorly drained soils of pedons 5 & 6 were in addition, limited by poor drainage. Current index of productivity of the soils indicate that 33.3 % of the soils were marginally suitable (pedons 2 & 4), another 33.3 % was currently not suitable (pedons 1 & 3) while 33.3 % was permanently not suitable (pedons 5 & 6) for the production of cashew. The soils were mainly limited by organic carbon and available nutrients (total N, available P and exchangeable K) while the poorly drained soils (pedons 5 & 6) were in addition, limited by poor drainage and flooding. Organic matter content correlates with cashew nut/m^2 (Ngatunga *et al*., 2001) and acts as the main source of phosphorus (Bleeker & Laut, 1987). Available P is an essential component of the cell nucleus in cashew (Widatmaka *et al*., 2014), however, delay maturity as well as shriveled seeds are sensitive symptoms of its deficiency (Aikpokpodion *et al*., 2009; Widiatmaka *et al*., 2014a). Consequently, Ibiremo *et al*., (2012) advocated the use of rock phosphates for treatment, while amended organic fertilizer improves the growth of the crop (Adeigbe *et al*., 2015).

Potential index of productivity (IPp) presents a situation where measures are put in place to remove limitations present in IPc. Figs. 2a and b show the suitability classes for Cashew production in Anyikang and Ibiaragidi. Out of a total area of 82.17 ha evaluated, 65.3 % was moderately suitable while 34.7 % of the land area was not suitable for Cashew production in Anyikang. Similarly, Ibiaragidi occupied a total area of 38.08 ha with 77.5 % considered moderately suitable while 22.5 % was not suitable for cashew production.

Limitations due to organic C, total N and available P were removed by simple application of organic matter (composted animal droppings and plant residues). Consequently, 66.7 % of the soils (pedons 1, 2, 3 & 4) were upgraded to moderately suitable status while 33.3 % were currently not suitable (pedons 5 & 6).

On the contrary, Udoh *et al*. (2015) classified the sandstone soils of Akwa Ibom as highly and moderately suitable for cashew production. It is therefore necessary to make a change of the current land use for the tract of land. Major limitations were due to availability of nutrients (a) expressed by exchangeable K in the entire soils while drainage caused a major challenge for soils in the poorly drained areas. Results obtained by Udoh (2015) identified soil physical properties as the main constraint for cashew production in Akwa Ibom state. Poorly drained soils have reduced availability for exchangeable cations (Bleeker & Laut, 1987) while nitrogen has been described as a necessity during the growth stage of cashew tree (O'Farrell *et al*., 2002). It is important therefore, to increase N, P and exchangeable K for increased production of cashew (Widiatmaka *et al*. 2014).

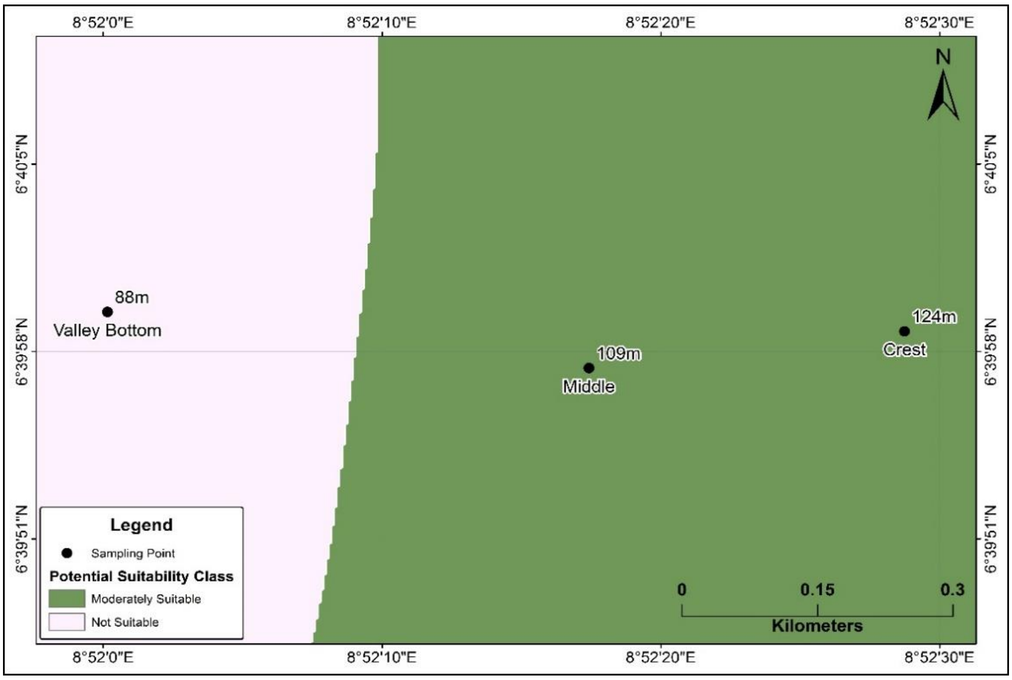

Fig. 2a: Potential suitability classes for Anyikang

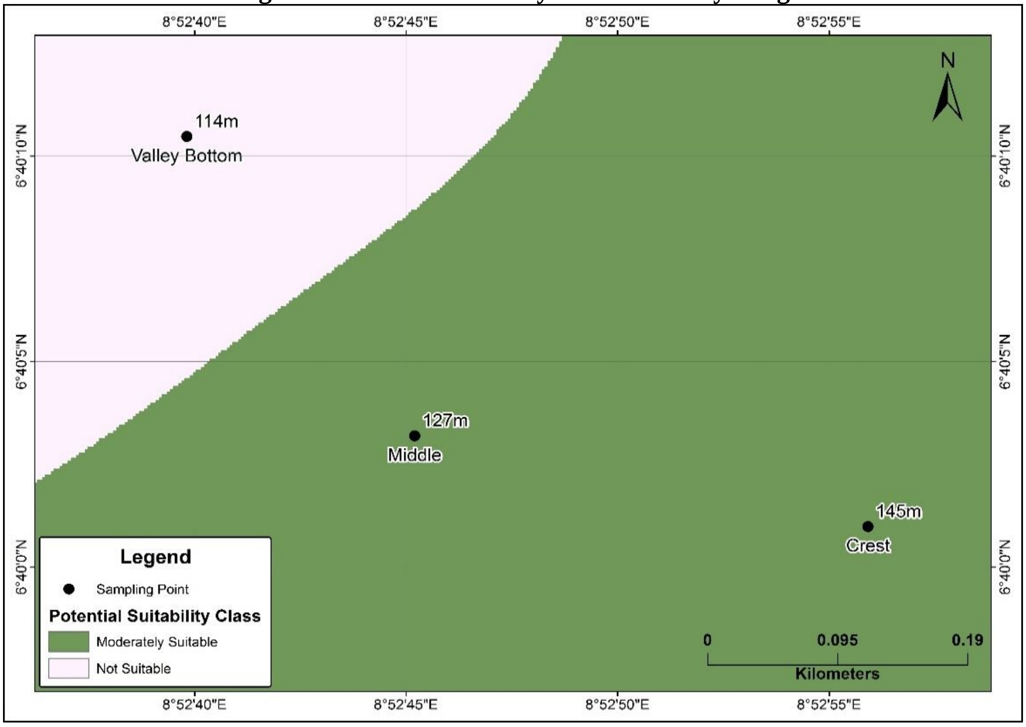

Fig. 2b: Potential suitability classes for Ibiaragidi

Table 5: Land characteristics data and rating of the soils

Ped	MAR mm/yr	MAT °C	Flood	Drain.	Text	Depth cm	CEC cmol/kg	BS %	pH (H_2O)	OC g/kg	TN	AP (ppm)	Exch. K (cmol/kg)	IPc	IPp
1	1983	27.9	Fo	Good	SL	195	15.3	87	5.9	0.35	0.03	6.8	0.11		
	S_1(100)	S_1(100)	S_1(100)	S_1(100)	S_1(90)	S_1(100)	S_1(100)	S_1(100)	S_1(100)	S_3(55)	S_3(55)	S_2(70)	S_2(70)	N_1fa(38.7)	S_2a(66.4)
2	1983	27.9	Fo	Good	SC	150	22.9	85	5.6	0.44	0.03	0.92	0.12		
	S_1(100)	S_1(100)	S_1(100)	S_1(100)	S_1(95)	S_1(100)	S_1(100)	S_1(100)	S_1(97)	S_3(60)	S_3(55)	S_3(58)	S_2(72)	S_3fa(41.5)	S_2a(69.1)
3	1983	27.9	Fo	Good	SCL	145	23	73	5.5	0.34	0.03	3.6	0.11		
	S_1(100)	S_1(100)	S_1(100)	S_1(100)	S_1(90)	S_1(100)	S_1(100)	S_1(100)	S_1(95)	S_3(55)	S_3(55)	S_2(65	S_2(70)	N_1fa(38.7)	S_2a(59.9)
4	1983	27.9	Fo	Good	SCL	87	18.8	80	5.2	0.65	0.08	2.56	0.12		
	S_1(100)	S_1(100)	S_1(100)	S_1(100)	S_1(90)	S_1(100)	S_1(100)	S_1(100)	S_1(85)	S_3(60)	S_3(60)	S_2(64)	S_2(72)	S_3fa(44.1)	S_2a(63.0)
5	1983	27.9	F1	FGW	SCL	200	36.0	88	5.3	0.46	0.03	3.25	0.10		
	S_1(100)	S_1(100)	S_3(45)	S_2(65)	S_1(90)	S_1(90)	S_1(100)	S_1(100)	S_1(88)	S_3(50)	S_3(55)	S_2(65)	S_2(60)	N_2wfa(22.4)	N_1wa(31.0)
6	1983	27.9	F1	FGW	SL	180	14.5	74	5.2	0.83	0.07	1.62	0.11		
	S_1(100)	S_1(100)	S_3(45)	S_2(65)	S_1(90)	S_2(60)	S_1(100)	S_1(100)	S_1(85)	S_3(60)	S_3(60)	S_2(60)	S_2(70)	N_2wfa(20.9)	N_1wa(26.9)

N/B: MAR; Mean annual rainfall, MAT; Mean annual temperature, FGW; fluctuating ground water, IPc; Current or actual index of productivity, IPp; potential index of productivity; w; wetness, f; soil fertility, a; available nutrients, S_2; Moderately suitable, S_3; Marginally suitable, N_1; Temporarily not suitable, N_2; Permanently not suitable for the land use under consideration

Conclusion and recommendations

The morphological, physical and chemical properties as well as classification of sandstone derived soils of Southern Guinea savanna in Bekwarra LGA were studied at various landscape positions and variability obtained in most soil properties. The soils were low in exchangeable cations and low to moderate in organic carbon with sand dominating the soil particle size distribution. However, soil CEC was moderate to high. At the subgroup category, pedon 1 was classified as Typic Haplustalf (Haplic Luvisols) while pedons 2 and 3 were classified as Typic Paleustalf (Haplic Luvisols) and pedon 4 as Typic Paleustalf (Rhodic Luvisols). Pedons 5 and 6 qualified as Aquic Udorthents (Hypereutric Gleysols). Land suitability evaluation indicated that the soils are most likely to improve upon proper management. Current index of productivity indicated marginal (S3) and not suitable classes (N1 & N2) which further advanced to moderately suitable (S2) and currently not suitable (N1), potentially for cashew production. It is advocated that farmer education should be intensified with the following site specific soil management procedures:

1. A combination of organic and inorganic fertilizers (Potassic fertilizer) should be used to boost soil productivity in the area.
2. Extremely acid soils affect the activities of most soil microbes and the availability of nutrients. Application of calcite and dolomite would not only attempt to solve acidity problems but also increase nutrients such as calcium and magnesium in the soils.
3. Mulching with organic plant residues should be encouraged. This will reduce the speed of run off and increase soil organic matter content thereby improving the structure of the sand dominated soils.

REFERENCES

[1] Adeigbe, O. O., Olasupo, F. O., Adewale, B. D. & Muyiwa, A. A. (2015). A Review of cashew research and production in Nigeria in the past four decades. Scientific research and essays, 10(5):196-209

[2] Agbede, O. O. (2009). Understanding soil and plant nutrition. Petra Digital press, Nigeria. Pp. 300.

[3] Ahukaemere, C. M & Akpan, E. I (2012). Fertility status and characterization of paddy soils of Amasiri in Ebonyi state, Southeastern Nigeria. PAT. 8(2): 159-168

[4] Ahukaemere, C. M. Akamigbo, F. O. R & Onweremadu, E. U (2013). Soil colour and organic matter content as indicators of soil quality in False bedded sandstone soils in Southeastern Nigeria, Nigeria journal of Agriculture, food and Environment. 9(3): 6-11

[5] Aikpokpodion, P. E., Uloko, B. & Edibo, G. (2009). Nutrient dynamics in soil and cashew (Anacardium occidentale L.) leaf and kernel in Kogi State, Nigeria. J. Appl. Biosci., 25: 1573-1578.

[6] Akamigbo,F. O. R. & Asadu, C. I. A (1982). Influence of parent Materials on the Soils of Southeastern Nigeria. East Africa Agricultural and forestry journal 48: 81-91.

[7] Akpan-Idiok, A. U & Ofem, K. I (2014). Physicochemical Characteristics, Degradation Rate and Vulnerability Potential of Obudu Cattle Ranch Soils in Southeast Nigeria, Open Journal of Soil Science, 4, 57-63

[8] Blake, G. R. (1965). Bulk density. In Methodsof soil Analysis, C. A. Black (ED).American Society of Agronomy 9; 374-396,Madison,Wisconsin.

[9] Bleeker, P. & Laut, P. (1987). A Soil Survey and Land Evaluation for Oil Palm and Cashew Nut of the Lockhart River Valley, Cape York, Queensland. Divisional Report 87 /1 CSIRO Institute of Natural Resources and Environment Division of Water Resources Research Canberra A.C. T. 67. Pp.

[10] Bowles, J. E. (1992). Engineering Properties of Soil and their Measurement 4th (ed); Mcgraw Hills, Boston, Inc. Pp.32-36

[11] Bulktrade & Investment Company Limited (1989). Soil and land use survey of Cross River State, main Report, Ministry of Agriculture and Natural Resources, Cross River State Nigeria.

[12] Donahue, R. L., Miller, R. W. & Shickluwa, J. C. (1983). An introduction to soils and plant Growth5th, Ed. prentice – Hall. Inc, Englewood cliffs, N. J, USA.

[13] Eshett, E. T. (1985).Soil characteristics and farming systems in Northern Cross River State of Nigeria. Ph. D. Thesis submitted to Department of Agronomy, University of Ibadan, Nigeria.

[14] Esu, I. E. (2004). Soil characterization and mapping for food security and sustainable environment in Nigeria. A key note address presented at the 29th Annual conference of the Soil Science Society of Nigeria held at the University of Agriculture, Abeucuta, Ogun State., December 6-10. 23pp.

[15] Esu, I. E. (2013). Optimization of Value chain crop yields in the Nigerian Agricultural Transformation Agenda through soil survey and land evaluation. Proceedings of the 29th Annual Conference of the Soil Science Society of Nigeria, Nassarawa State University, Keffi, Nigeria. Pp. 1-9

[16] Esu, I. E. (2010). Soil characterization, Classification and survey. Hinneman Educational Book publishers Plc. Nigeria p 233

[17] FAO. (1994). Eco-crop 1. The adaptability level of the FAO crop environmental requirements database. Version 1.0. Land Resources Management and Conservation Service, FAO, Rome.

[18] FAOSTAT. (2013). Food and Agriculture Organization Statistics.

[19] Gee, G. N. & Bauder, J. N. (1986). Particle size Analysis. part 1. physical and mineralogical methods, Pp404-408.Madison, Wisconsin. USA.

[20] Holland, M. D. G., Barton, A. D & Morph, S. T (1989). Land Evaluation for Agricultural Recommendation of Cross River National Park. Oban Division, prepared by Odwki, in collaboration with INNF.

[21] Ibanga, I. J. (2006). Soil studies: The pedological Approach. Mesot printing and computers, Calabar, Nigeria.

[22] Ibiremo, O. S., Ogunlade, M. O., Oyetunji, O. J. & Adewale, B. D. (2012). “Dry matter yield and nutrient uptake of cashew seedlings as influenced by arbuscular mycorrhizal inoculation, organic and inorganic fertilizers in two soils in Nigeria,” ARPN: Journal of Agricultural and Biological Science, 7(3): 196–205

[23] Laffan, et al., (1998). Some Properties of soils on Sandstone, granite and dolorite in relation to Dryand wet Eucalypt forest types in Northern Tasmania.

[24] Landon, J. R. (1991). Booker Tropical Soil Manual. A soil book for soil Survey and agricultural evaluation in the tropics and subtropics, Longman NewYork. Pp.474

[25] Lawal, B. A, Adeboye, M. K. A, Sado, P.A T, Elebiyo, M. G & Nwajoku, C. R. (2012). Properties, Classification and Agricultural potentials of lateritic soils of Minna in humid agroecological zone, Nigeria.

[26] Naganori Y, Makoto N, Tetsuo M.& Teruo H. (1984). Formation of Imogolite and allophane in shattered sandstone underlying brown forest soils in Ehime Japan.

[27] Ngatunga, E. L., Cools, N., Dondeyne, S. & Deckers, J. A. (2001). Soil suitability for cashew in South Eastern Tanzania. The Land (5)1: 3-16

[28] Nitidæ (2019). The West African Cashew Sector in 2018; General Trends and Country Profiles: Analysis of Cashew Production, Processing and Trade in West Africa. Pierre RICAU

[29] Nugawela, P. A. & Oroch, R. (2005). Cashew Subsector Strategic Framework. Promoting subsector strategic Framework. Promoting proper opportunities through commodities and service markers. Department for International Development (UK)- Nigeria

[30] O’Farrell, P., Armour, J. & Reid, D. (2002) “The effect of nitrogen on cashew in north Queensland,” RIRDC Publication no W02/001, RIRDC Project no DAQ-257A

[31] Ofem, K. I., Akpan-Idiok, A. U., Afu, S. M & Esu, I. E (2016). Land suitability evaluation of residual and colluvio- alluvial soils for oil palm cultivation in Biase, Cross River State, Nigeria, African Journal of Agricultural Science and Technology (AJAST) Vol. 4, (4): 683-691

[32] Ogunsina, B. S. & Lucas, E. B. (2008). Development of a manually operated cashew juice extractor. Agricultural Engineering International: The CIGR E J. 3(2)

[33] Ogunwale, J. A. & Ashaye, T. I. (1975). Sandstone-Derived Soils of a Catena at Iperu, Nigeria.

[34] Paul, E. A. & Clark, F. E (1989). Soil Microbiology and Biochemistry. Academic press, San Diego.

[35] Sambo, E. E, Ufoegbune, G. C, Eruola, A. O. & Ojekunle, O. Z. (2016) Impact of Rainfall Variability on Flooding of Rivers in Cross River Basin, Nigeria. Nigerian Meteorological Society (NMETS), "Climate Variability and Change: Impact, Science, Innovation and Policy" at Federal College of Education Osiele, Abeokuta. 21 - 24 November, 2016

[36] Souza, D. F., Barbosa, R. S., Bezerra da Silva, Y. J., Soares de Moura, M. C. Porto de Oliveira, R. & Martins, V. (2019). Genesis of sandstone-derived soils in the Cerrado of the Piauí State, Brazil. Ambiente & Água - An Interdisciplinary Journal of Applied Science ISSN 1980-993X – doi:10.4136/1980-993X

[37] Schoenmaker, B. (1998). Growing Cashew in Costa Rica. Coordinator Wageningen Agricultural University, 41pp

[38] Soil Survey Staff (2012). Field book for describing and sampling soils, Version 3.0. National Soil Survey Centre, Natural Resources Conservation Service, USDA Lincoln Nebraska.1-1:9-13.

[39] Stevenson, T. (2005). The Sothby's Wine Encyclopedia. Dorling Kindersley. Pp. 16.

[40] Sys, I. C., Ranst, E. V., Debaveye, I. J. & Beernaert, F. (1993). Land evaluation part 3: Crop requirements. Agricultural publications No. 7. 189pp.

[41] Udo, E. J., Ibia, T. O, Ogunwale, J. A., Ano, A. O & Esu, I. E (2009). Manual of Soil, Plant and Water Analyses. Sibon books Ltd. Lagos, Nigeria.

[42] Udoh, B. T (2015). Suitability of soils derived from sandstone and beach sands for Cashew (Anacardium occidentials and Coconut (Cocos nucifera) cultivation in the Niger Delta Area, Nigeria. Sky journal of soils and Environmental management, 4(2): 22-33.

[43] Widiatmaka, A., S., Anas, I., Usman, D., Muhammad, H. & Ari, K.. (2014). Establishing Land Suitability Criteria for Cashew (Anacardium occidentale L.) in Indonesia. Applied and Environmental Soil Science, 14 Pp. http://dx.doi.org/10.1155/2014/743194

AUTHORS

First Author – Ofem, K. I, Department of Soil Science, University of Calabar, Nigeria
Second Author – Abua, S. O, Department of Soil Science, University of Calabar, Nigeria
Third Author – Umeugokwe, C. P, Department of Soil Science, University of Nigeria, Nsukka
Fourth Author – Ezeaku, V. I, Department of Soil Science, University of Nigeria, Nsukka
Fifth Author – Akpan-Idiok, A. U, Department of Soil Science, University of Calabar, Nigeria