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CHARACTERISTICS AND CLASSIFICATION OF SOILS DEVELOPED OVER COASTAL PLAIN SAND AND SHALE PARENT MATERIAL IN ABIA STATE NIGERIA

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ABSTRACT
A semi-detailed soil survey of the land of Ikwuano Local Government Area Abia State South East Nigeria was made with the aid of the digitized map. Pedons in the identified mapping units were sampled and studied for their morphology, physical and chemical properties (e.g. soil colour, texture, pH, CEC, %OC, base saturation). Soils texture ranged between loamy sand / sandy loam at the A/Ap horizon and sandy clay loam/clay in the B horizon. There was a general clay increase with depth in most of the profiles. The soils were acidic, with pH range of 4.5 - 5.7. Cation exchange capacities of the soils ranged between 2.48 and 27.64 Cmol/kg soil. Base saturation of the soils ranged from 15.4 - 86.3%. Organic carbon ranged between 1.6 – 29.6 g/kg soil. The soils at the order level were classified as Inceptisols and at the series level were classified as Ahiara series.

Key words: soils, coastal plain, sand and shale parent material

INTRODUCTION
Decisions on land use are made indiscriminately based mainly on economic and political considerations, with little or no consideration for the biophysical status of the soils. The shortage of prime land in some cases have led to land use conflicts and environmental conflicts.The knowledge of the pattern of soil distribution and the characteristics of each unit of soil are very essential for a better understanding, use and management of soils (Nuga,2009). In order to avoid a situation in which prime agricultural land will be lost to other land uses and environmental degradation, there is the need for information on the quality of land / soils in the local government area. The lack of comprehensive soil map indicating soil types and nutrient requirements of each crop has led to indiscriminate application of mineral fertilizers, which poses more risk on the fragile soils (Ayeni, 2011).

A soil survey describe the characteristics of the soils in a given area, classifies soils according to a standard system of classification, plots boundaries of the soils on a map and make predictions about the behaviour of the soils (USDA, 1993). The information helps in the development of land use plans, evaluates and predicts the effects of land use on the environment (Shepande,2002). The objectives of most soil survey investigations are to provide data for the rational planning and adjustment of land use (Hubrechts et al, 2004). Optimum crop production can be achieved through the rational use of fertilizers accompanied with other management practices that takes cognizance of the variability of the soils (Omotosho and Akinbola, 2007).

The shortage of prime land in some cases have led to land use conflicts and environmental conflicts.The knowledge of the pattern of soil distribution and the characteristics of each unit of soil are very essential for a better understanding, use and management of soils (Nuga, 2009). In order to avoid a situation in which prime agricultural land will be lost to other land uses and environmental degradation, there is the need for information on the quality of land / soils in the local government area.The absence of this soil information contributed to the problem of decreasing agricultural productivity per unit area, (Aticho et al ,2011). In addition ,lack of Soil resource information is a major factor in the wasteful and environmental degrading exercise of inappropriate blanket recommendation of fertilizers(Sokouti et al, 2011) .Land/soil must be evaluated appropriately as a means of conserving the soil resource(Fasina, 2008) There is the need therefore to characterise and classify the soils of the local government area for sustainable land use practices. This study was therefore undertaken to characterize and classify the soils of the study area.

MATERIALS AND METHODS

The study area is located in the South eastern region of Nigeria. It is one of the seventeen local government areas making up Abia State. The area lies between latitudes 5° 20' and5° 30'N, longitudes 7° 28' and 7° 42'E, and it covers an area of about 310 sq.Km (Fig.1 and 2.) with elevation ranging from 109 to 152m above mean sea level. The study area is bounded in the north by Umuahia LGA,in the south by Ikot-Ekpene,Akwa Ibom State, in the east by Bende LGA and in the west by Isiala Ngwa LGA. The climate is the wet and dry type classified as Tropical rainy (Aw) climate by Koppen (1923). The climatic regime is characterised by erosive tropical rainfall that may cause severe erosion problems to hill slope soils. The average annual rainfall ranges between 1,800 and 2,500 mm / year, with the peak between July and August. This abundant rainfall feeds an extensive hydrological system, which includes the Qua Ibooe, Inyang, Ntamiri and Anya Rivers. The mean annual maximum temperature is 31^oC , but mean monthly values vary between $20\,^oC$ and 34^oC

The area lies within the rainforest vegetation zone; hence rainfed cultivation forms the base of agricultural production. However the native vegetation in a number of places in the study area has been altered by human activities to become secondary forests, farmlands, built up areas, etc. The geological materials found in the area belong to the three periods viz: Quaternary, Tertiary and Cretaceous. In the Quaternary are alluvial deposits and in the Tertiary are coastal plain sands, lignite formation, Bende Ameke formation and Imo shales. The Cretaceous contain the Upper coal measures, false bedded sandstones, lower coal measures, Asata Nkporo shale group, and Asu river group (Fig.3).

Fig 1. Map of Nigeria with Abia state highlighted.

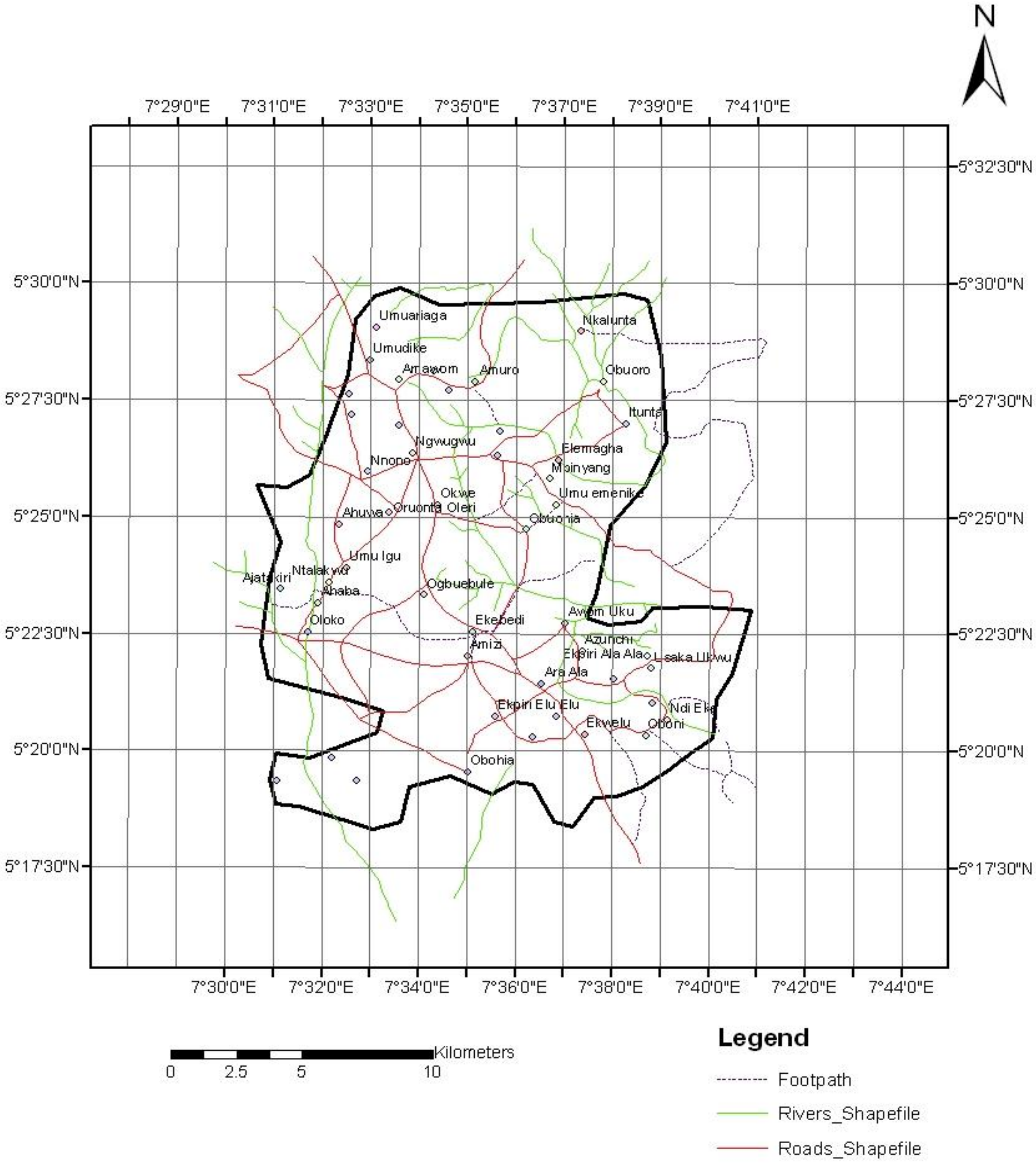

Fig.2. Map of the study area.

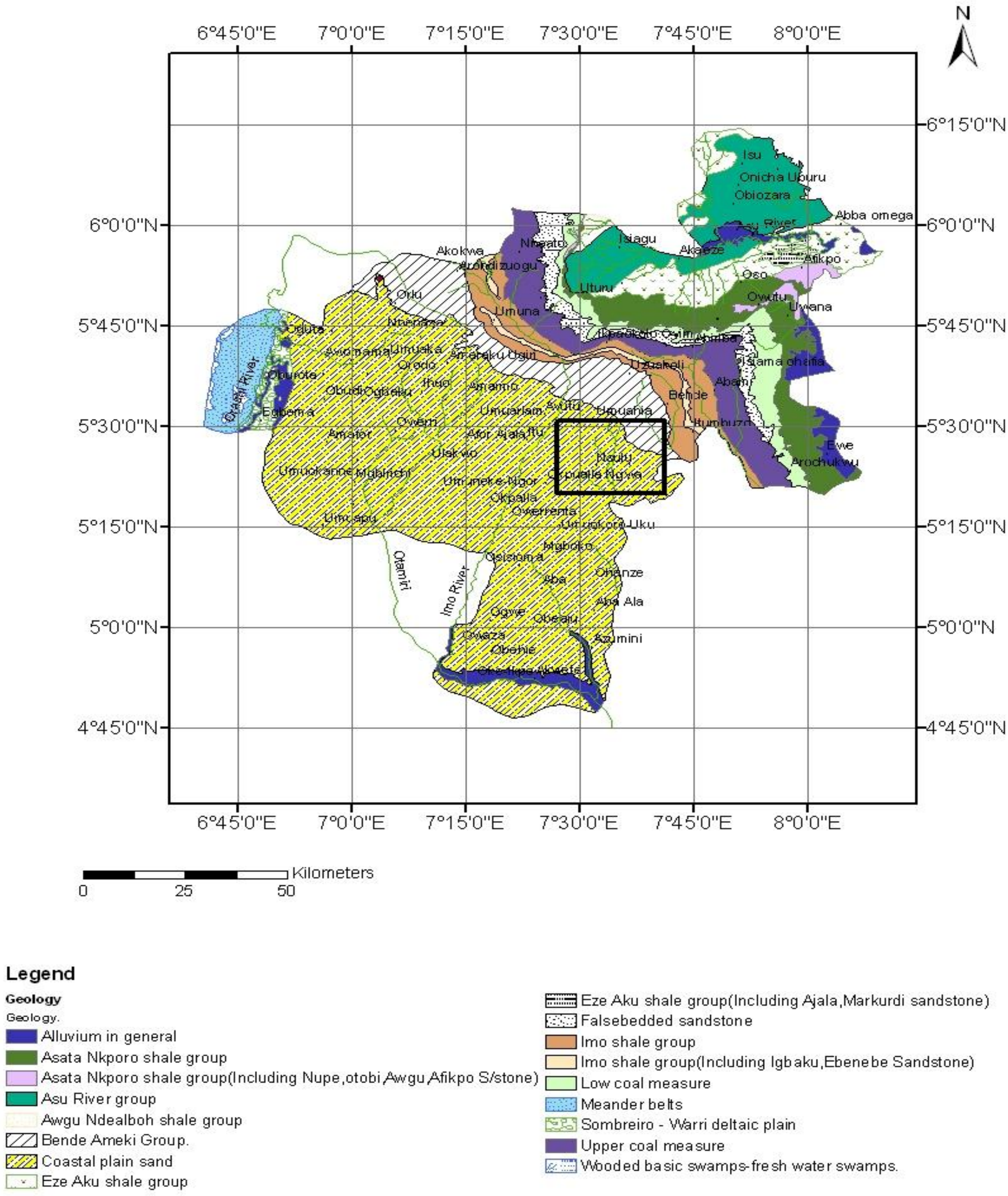

Figure 3: Geology map of Old Imo State with the study area within the highlighted box.

Soil Characterization

Auger observations at depths of 0- 15cm, 15- 30cm, 30-60cm, 60-90cm, 90-120cm, were made at each of the grid nodes derived from the digitized map. At each node point, the morphological descriptions of the soils were made. Characteristics such as soil colour, texture (by feel method), consistence and land cover, were recorded according to the FAO (1990) guidelines. The results of this exercise facilitated the delineation of the study area into mapping units, which were made up of areas of same morphological characteristics.

Profile pits were dug at points typical of each mapping units. The profiles were described and sampled according to the FAO (1990) guidelines. The samples were taken to the laboratory for analysis. The geographical co-ordinates of the profiles were determined with a Global Positioning System (GPS) device.

The collected soil samples were air dried and passed through a 2mm sieve. Particle size distribution of the less than 2 mm fine grain fractions was determined by the hydrometer method as described by Gee and Bauder (1986). Soil pH was determined in a 1:2.5 soil/water suspensions. The soil organic carbon was determined by the Walkley and Black method described by Nelson and Sommers (1982). Exchangeable cations and the cation exchange capacity were determined by the method of Thomas (1982). Base saturation was estimated as the sum of exchangeable bases divided by the CEC.

The soils were classified using three different classification systems viz; Soil Taxonomy 10th Edition (Soil Survey Staff. 2006), World Resource Base (FAO/ISRIC/IUSS, 2006) and lastly Series classification was done using Moss (1957) as modified by Ojanuga (1998), classification of soils on sedimentary materials.

RESULTS AND DISCUSSION

Morphological and Textural properties of Soils of the mapping units

The soils of this mapping unit have colour matrix that ranged from dark brown / reddish brown (10YR2/1 – 5 YR 3/1) at the A/Ap layers or topsoil to 5YR4/6 in the subsoil. The texture of the surface soils ranged between sand and sandy loam and that of the subsoil sandy loam - sandy clay (Tables 1 and 2).The total sand content of the soils, decrease with increase depth, with a range of 260 – 800 g/Kg. The clay fraction of the soils increased with increase in profile depth The surface horizon had clay fraction of between 100 - 460 g/Kg, while that of the subsurface horizons ranged between 100 – 600 g/Kg. There is an increase in clay content down the profile. This subsoil accumulation of clay can be attributed partly to illuviation and flocculation. The silt content in the profiles studied in this mapping unit has values of 20 -140 g/Kg.The soils are deep (>100cm) and well drained. The soils are loose to firm and of weak to medium sub angular blocky structure. Stones and concretions are absent in most profiles.

On the other hand, the soils of mapping unit 2 have colour matrix that ranged from reddish brown/ dark brown (2.5YR5/0 - 10YR 4/3) at the A/Ap horizon to strong brown (7.5YR4/4) in the B horizons. The texture of the soils ranged between sandy clay loam / sandy clay at the A/Ap horizon to sandy clay/clay in the B horizons (Tables 3 and 4).

The total sand content of the soils decrease with increase depth, with a range of 280 – 700 g/Kg. The clay fraction of the soils increased with increase in profile depth .The clay value ranged from 200 g/Kg at the surface to 640 g/Kg in the B horizons. The silt content in the profiles studied in this mapping unit has values of 60 – 800 g/Kg. The dominant structure in the profiles of this mapping unit was subangular blocky. Mottling occured in some profiles of this mapping unit. The mottles were red and prominent in the B horizons.

Chemical Properties of the soils

The soils of mapping unit 1 are strongly acidic to medium acidic in reaction.The pH (H_20) of the soils in this mapping unit ranged from 4.10 - 6.37 in the surface and 4.10 – 5.18 in the subsurface (Table 5).The degree of leaching , nature of the parent material, dominant clay mineralogy and intensity of microbial activities going on within the soils are likely factors affecting the pH of the soil. The total nitrogen is very low to low with values between 0.4 and 1.0

g/Kg in the surface layers and 0.4 - 9.0 g/Kg in the sub soils. Organic carbon content is very low in all the profiles of this mapping unit with values < 20 g/Kg. The value decreased regularly with depth. The low values of the total nitrogen is a relection of losses through leaching and crop removal. The farming system in the study area is such that tuber crops like cassava are predominant with few few farmers having nitrogen replenishing crops like cowpea and groundnuts as part of the crops on their farms. Available phosphorus content in the mapping unit is low with value of 1.03 – 9.45 mg/kg soil. The cation exchange capacity value ranged between 3.50 – 5.06 Cmol / kg in the soils of the mapping unit. Calcium is the most dominant cation followed by Magnesium in all the pedons (Ca>Mg>Na>K). The base saturation in the profiles of the mapping unit has an average range of 27.05% - 56.98%. The BS is generally < 50% in the the profiles . For mapping unit 2, the pH (H_20) of the soils in this mapping unit ranged from 4.41– 7.22 in the A/Ap horizon and 4.45– 7.72 in the subsurface (Table 6). These values make the soils to be strongly acidic to neutral. The total nitrogen is very low to with values between 0. 4 and 0.5 g/Kg in the A/Ap horizon, which decrease to 0.3 g/Kg in the sub soils. Available phosphorus content in the mapping unit ranged between 1.45 – 7.65mg/kg soil. The cation exchange capacity is low with value range of 5.54– 8.00 Cmol / kg in the soils of the mapping unit. . Magnesium is the most dominant cation followed by calcium in all the pedons (Mg>Ca>Na>K). The base saturation in the profiles of the mapping unit is averagely > 35% in most profiles.

The profiles in the two mapping unit exhibited high Fe active ratio ranging between 0.33 and more than unity(Tables 7 and 8). This indicates higher proportion of oxides in the amorphous or non crystalline forms within the profiles. The active ratio has been used by some workers (e.g. Stonehouse and Arnaud,1971, Udo, 1980) to distinguish betwen poorly drained and well drained soils. Soils having active ratio value > 0.35 were classified as poorly drained and those with values < 0.35 as well drained. This diagnostic index when applied to the soils of this study area thus placed them in the poorly drained class. This was evident fom the field observation - profile description where most of the profiles were observed to be moist throughout. Hence , because the soils were poorly drained, the weathering into crystalline Fe-oxides was much less and so most of the sequioxides is present in the amorphous non-crystalline forms. The values of the ratio of oxalate extractable Fe and Al to dithionite extractable forms in the soils of the study area show the reactivity of the sesquioxides. The values obtained ranged from 0.33 to well over unity. The values of amorphous Fe is high relative to the amount of crystalline Fe. This is similar to the findings of Udo (1980) on Bende soils, where the values of Fe_d were very low in soils derived from shale parent material classified as Inceptisols. Similar observations were made by Aghimien et al (1988) and Akinbola (2001) in soils of southern Nigeria.This higher iron reactivity indicates lower degree of ageing of the minerals pointing to the fact that the rate of release of iron from primary mineral lattice seem to exceed rate of crystallization.The relative high ratio thus points to the fact that a large fraction of the the iron is in the amorphous forms. The drainage condition of the soils is a reducing factor in the crystallization of iron minerals. Amorphous materials are regarded as being formed at the initial stage of hydrolysis. These results thus suggest that the soils are young soils.

Table 1. Morphological Description of Typical Profiles of mapping unit 1

Profile No	Horizon	Depth (cm)	Colour (moist)	Texture	Structure	Consistence	Rootlets	Mottle	Concretions	Boundary	Others
399	Ap	0-24	$5YR^3/_3$	SL	Sabk	L	Ffirt	-	-	CS	-
	AB	24-50	$5YR^4/_6$	SCL	Sabk	L	Fvfirt	-	-	CS	-
	Bt1	50-80	$7.5YR^4/_4$	SCL	Sabk	L	Fvfirt	-	-	DS	-
	Bt2	80-106	$7.5YR^4/_4$	SCL	Sabk	L	Fvfirt	-	-	DS	-
	BC	106-120	$7.5YR^4/_4$	SCL	Sabk	L	Fvfirt	-	-	-	-
400	Ap	0-22	$7.5YR^3/_3$	SL	Fsabk	L	Mfirt	-	-	GW	-
	AB	22-50	$5YR^4/_4$	SL	Fsabk	L	Fcort	-	-	CW	-
	B1	50-73	$7.5YR^4/_4$	SCL	Fsabk	L	Fcort	-	-	CW	-
	B2	73-120	$7.5YR^4/_4$	SCL	Fsabk	L	Fcort	-	-	-	-
405	Ap	0-20	$5YR^3/_2$	SL	Fsabk	L	Mmed	-	-	DS	-
	AB	20-58	$10YR^3/_2$	L	Fsabk	L	Mco	-	-	GS	-
	Bt1	58-76	$10YR^4/_4$	CL	Fsabk	Fr	Fmed	-	-	GS	-
	Bt2	76-105	$7.5YR^4/_6$	CL	Sabk	Fr	-	-	-	CS	-

Key: 1. : SL = sandy loam, SCL =sandy clay loam, SC= sandy clay, L =loam, C=clay, LS= loamy sand
2. Vfsabk= very fine subangular blocky, Fasbk= fine subangular blocky, Masbk= medium subangular blocky, Cogr= coarse grain
3. L = loose, F r= Friable, Vfi = very firm,Wstk = wet sticky, Dh = dry hard
4. CW= clear wavy,CS=clear smooth, GS=gradual smooth,, DS = diffuse smooth,DW= diffuse wavy
5. MCrt = Many coarse roots, MFrt = Many fine roots, Fcrt = few coarse roots, Fmdrt = few medium root, Ffirt =few fine roots

6. Mmdmt = many medium mottles, Ffi = few fine mottles, Fco = few coarse mottles

Table 2: Particle Size Distribution of Soils of Mapping Unit 1

ProfileID	Elevation(masl)	Coordinate	Horizon	Horizon Depth (cm)	Sand	Clay	Silt	Silt/Clay ratio	Texture
						g/Kg			
399	88	5° 19' 23.9'' N 7° 33' 57.2'' E	Ap	0-24	400	460	140	0.30	C
			AB	24-50	300	520	180	0.35	C
			Bt1	50-80	620	320	60	0.19	SCL
			Bt2	80-106	540	400	60	0.15	SC
			BC	106-120	480	440	80	0.18	SC
400	127	5° 20' 18.6'' N 7° 35' 14.7'' E	Ap	0-22	520	400	800	2.0	SC
			AB	22-50	500	420	800	1.9	SC
			B1	50-73	740	200	600	3.0	SL
			B2	73-120	660	290	500	1.7	SCL
405	69	5o 21' 33.0'' N 7o 38' 54.7'' E	Ap	0-20	520	340	140	0.41	SCL
			AB	20-58	720	240	40	0.17	SCL
			B1	58-76	720	240	40	0.17	SCL
			B2	76-105	700	260	40	0.15	SCL

Table 3. Morphological Description of Typical Profiles of mapping unit 2

Profile No	Horizon	Depth (cm)	Colour (moist)	Texture	Structure	Consistence	Rootlets	Mottle	Concretions	Boundary	Others
401	Ap	0-15	2.5YR$^{5}/_{0}$	SL	Sabk	Fr	Mmdrt	-	F Fe/mn	CW	Fst
	AB	15-32	2.5YR$^{5}/_{0}$	SL	Sabk	Fr	Mmdrt	-	F Fe/mn	CW	Fst
	Bt1	32-60	7.5YR$^{2}/_{0}$	SL	Sabk	Fr	Mmdrt	-	M Fe/mn	DS	Fst
	Bt2	60-80	7.5YR$^{3}/_{2}$	SL	Sabk	L	Vfcort	-	M Fe/mn	CS	Fst
	BC	80-110	7.5YR$^{3}/_{3}$	SCL	Sabk	L	Vcort	-	M Fe/mn	-	Fst
402	Ap	0-10	10YR$^{4}/_{3}$	C	Vfasbk	Fi	Mmedrt	-	-	DS	
	AB	10-25	5YR$^{4}/_{4}$	C	Vfasbk	Fi	Mmedrt	-	C Fe	DS	
	Bt1	25-40	10YR$^{5}/_{3}$	C	Vfasbk	Fi	Mmedrt	Mmed (2.5YR ¾)	C, Fe	DS	
	Bt2	40-60	10YR$^{5}/_{3}$	C	Vfasbk	Fi	Mmed	Mmed (2.5YR ¾)	C, Fe	-	
403	Ap	0-15	7.5YR$^{4}/_{3}$	SCL	Fsabk	Fi	Ffirt	-	-	CW	
	AB	15-48	10YR$^{4}/_{4}$	SCL	Fsabk	Fi	Fmdrt	-	-	CW	
	B1	48-75	10YR$^{4}/_{6}$	SCL	Vfsabk	Fr	Ffirt	7.5YR$^{4}/_{6}$ Mmdmt	-	CW	
	B2	75-100	10YR$^{4}/_{6}$	SCL	Vfsabk	Fr	Fvfirt	7.5YR$^{4}/_{6}$ Mmdmt	-	-	
404	Ap	0-10	5YR$^{3}/_{2}$	CL	Vfasbk	L	Mfi	-	-	CS	-
	AB	10-25	10YR$^{3}/_{2}$	CL	Vfasbk	Fr	Ffi	Mmed 2.5 YR$^{4}/_{6}$	M Fe/mn	CS	-
	B1	25-45	10YR$^{3}/_{2}$	CL	Fasbk	Fi	Ffi	Mmed 2.5 YR$^{4}/_{6}$	M Fe/mn	DW	-
	B2	45-57	10YR$^{5}/_{3}$	C	Masbk	Vfi	-	Mmed 2.5 YR$^{4}/_{4}$	M Fe	DS	Slicken side
	BC	57-110	10YR$^{5}/_{3}$	C	Mabk	Vfi	-	Mmed 2.5 YR$^{4}/_{4}$	VM Fe	-	-

Table 4:.Particle Size Distribution of Soils of Mapping Unit 2

ProfileID	Elevation(masl)	Coordinate	Horizon	Horizon Depth (cm)	Sand	Clay	~~Silt~~	Silt/Clay ratio	Texture
						g/Kg			
401	96	5^{o} 27' 53.8'' N 7^{o} 38' 00.6'' E	Ap	0-15	640	300	60	0.20	SCL
			AB	15-32	600	360	40	0.11	SC
			Bt1	32-60	700	200	100	0.50	SL
			Bt2	60-80	680	260	60	0.23	SCL
			BC	80-110	620	300	80	0.27	SCL
402	43	5^{o} 27' 54.0'' N 7^{o} 37' 37.6'' E	Ap	0-10	600	340	60	0.18	SCL
			AB	10-25	580	340	80	0.24	SCL
			B1	25-40	560	340	100	0.29	SCL
			B12	40-60	560	380	60	0.16	SC

Table 4: (contd).Particle Size Distribution of Soils of Mapping Unit 2

ProfileID	Elevation(masl)	Coordinate	Horizon	Horizon Depth (cm)	Sand	Clay	Silt	Silt/Clay ratio	Texture
						g/Kg			
403	39	5^o 27' 48.3'' N 7^o 37' 35.0'' E	Ap	0-15	560	400	400	1.0	SC
			AB	15-48	580	380	400	1.1	SC
			B1	48-75	620	340	400	1.2	SCL
			B2	75-100	440	480	800	1.7	C
404	35	5^o 28' 04.4'' N 7^o 37' 59.7'' E	Ap	0-10	300	600	100	1.7	C
			AB	10-25	280	620	100	1.6	C
			B1	25-45	260	640	100	1.6	C
			B2	45-57	420	260	320	1.2	L
			BC	57-110	540	320	140	0.4	SCL

Table 5 : Chemical properties of the soils of mapping unit 1

ProfileID	Horizon	Depth	pH(H_2O)	pH(Kcl)	Ca	Mg	K	Na	EA	TEB	ECEC	%Base Sat	OC g/Kg	Total N g/Kg	C/N Ratio	Av.P mg/kg
								cmol / kg								
399	Ap	0-24	4.78	4.10	0.44	0.97	0.04	0.45	4.60	1.90	6.50	29.23	2.8	0.3	9.33	3.90
	AB	24-50	4.95	4.17	0.45	0.88	0.08	0.46	4.00	1.87	5.87	31.86	2.0	0.2	10.00	4.80
	Bt1	50-80	4.91	4.20	0.35	0.95	0.05	0.46	2.40	1.81	4.21	42.99	4.6	0.5	9.20	2.90
	Bt2	80-106	4.79	4.28	0.40	0.97	0.06	0.44	2.70	1.87	4.57	40.92	2.9	0.3	9.67	3.40
	BC	106-120	5.09	4.30	0.39	0.88	0.04	0.43	4.10	1.74	5.84	29.79	2.4	0.2	12.00	3.90
400	Ap	0-22	5.62	4.95	0.71	0.95	0.04	0.48	4.10	2.18	6.28	34.71	2.4	0. 2	12.00	3.40
	AB	22-50	5.47	4.98	0.60	0.80	0.04	0.38	4.60	1.82	6.42	28.35	3.2	0.3	10.67	1.95
	Bt1	50-73	4.93	4.35	0.46	0.97	0.11	0.41	2.70	1.95	4.65	41.94	3.6	0.4	9.00	1.45
	Bt2	73-120	4.99	4.35	0.45	0.95	0.05	0.04	4.50	1.49	5.99	24.87	4.0	0.4	10.00	5.30
405	Ap	0-20	5.17	4.10	0.33	0.86	0.16	0.68	4.70	2.03	6.73	30.16	6.0	0.6	10.00	6.30
	AB	20-58	4.41	4.08	0.28	0.66	0.11	0.63	3.60	1.68	5.28	31.82	15.4	1.5	10.27	8.10
	B1	58-76	5.26	4.06	0.29	1.79	0.08	0.60	3.20	2.76	5.96	46.31	3.0	0.3	10.00	6.75
	B2	76-105	5.15	4.11	0.24	0.76	0.08	0.70	3.80	1.78	5.58	31.90	4.8	0.5	9.60	6.75

Table 6. : Chemical properties of the soils of mapping unit 2.

ProfileID	Horizon	Depth	pH(H_2O)	pH(Kcl)	Ca	Mg	K	Na	EA	TEB	ECEC	%Base Sat	OC g/Kg	Total N g/Kg	C/N Ratio	Av.P mg/kg
								cmol / kg →								
401	Ap	0-15	7.22	7.18	0.65	2.04	0.48	0.70	3.40	3.87	7.27	53.23	4.2	0.4	10.50	3.90
	AB	15-32	7.72	7.40	1.50	1.89	0.20	0.56	3.50	4.15	7.65	54.25	4.1	0.4	10.25	3.40
	Bt1	32-60	7.43	7.42	1.38	1.87	0.21	0.74	3.80	4.20	8.00	52.50	10.1	1.0	10.10	1.95
	Bt2	60-80	7.44	7.42	1.20	1.50	0.16	0.55	2.70	3.41	6.11	55.81	6.6	0.7	9.43	2.90
	BC	80-110	7.33	7.26	0.98	1.23	0.19	0.62	3.90	3.02	6.92	43.64	7.1	0.7	10.14	1.60
402	Ap	0-10	4.41	3.87	0.92	1.15	0.17	0.60	2.70	2.84	5.54	51.26	5.1	0.5	10.20	4.80
	AB	10-25	4.45	3.67	0.51	1.11	0.18	0.68	3.80	2.48	6.28	39.49	4.5	0.5	9.00	1.45
	B1	25-40	4.90	3.63	0.41	0.80	0.18	0.63	4.20	2.02	6.22	32.48	10.0	1.0	10.00	4.35
	B12	40-60	4.30	3.55	0.30	0.68	0.18	0.61	5.50	1.77	7.27	24.35	6.7	0.7	9.57	6.30
403	Ap	0-15	5.33	4.22	0.40	1.09	0.16	0.61	4.90	2.26	7.16	31.56	4.9	0.5	9.80	6.30
	AB	15-48	5.14	4.00	0.36	1.05	0.14	0.70	3.80	2.25	6.05	37.19	4.7	0.5	9.40	7.20
	Bt1	48-75	4.74	3.96	0.36	0.95	0.12	0.62	3.50	2.05	5.55	36.94	3.5	0.4	8.75	6.70
	Bt2	75-100	4.68	4.01	0.33	0.82	0.11	0.73	5.10	1.99	7.09	28.07	3.6	0.4	9.00	5.40
404	Ap	0-10	5.09	4.44	0.43	1.11	1.07	0.70	4.60	3.31	7.91	41.85	5.1	0.5	10.20	7.65
	AB	10-25	4.72	4.04	0.53	1.07	0.26	0.69	5.40	2.55	7.95	32.08	3.1	0.3	10.33	6.30
	B1	25-45	4.47	3.90	0.49	1.13	0.47	0.81	5.20	2.90	8.10	35.80	2.5	0.3	8.33	5.87
	Bt1	45-57	4.53	3.86	0.46	1.15	0.23	0.73	4.30	2.57	6.87	37.41	13.8	1.4	9.86	5.40
	BC	57-110	4.78	3.72	0.54	1.42	0.17	0.75	4.70	2.88	7.58	37.99	12.8	1.3	9.85	4.95

Table 7. : Percentages of Oxalate and Dithionite Extractable R_2O_2 and Active Fe and Al Ratio in profiles of Mapping Unit 1

ProfileID	Horizon	Horizon Depth	Fe(Oxal)%	Fe(DCB)%	Active Fe ratio (Fe_o/Fe_d)	Al(oxala)%	Al(DCB)%	Active Al ratio (Alo/Ald)
399	Ap	0-24	0.455	0.356	1.28	0.563	0.405	0.04
	AB	24-50	0.611	0.483	1.26	0.537	0.393	0.04
	Bt1	50-80	0.509	0.636	0.80	0.576	0.524	0.04
	Bt2	80-106	0.455	0.356	1.28	0.616	0.511	0.05
	BC	106-120	0.382	0.636	0.60	0.642	0.486	0.05
400	Ap	0-22	0.254	0.738	0.34	0.603	0.459	0.05
	AB	22-50	0.356	0.713	0.50	0.563	0.446	0.04
	Bt1	50-73	0.432	0.458	0.94	0.524	0.511	0.04
	Bt2	73-120	0.331	0.433	0.76	0.485	0.524	0.04
405	Ap	0-20	0.280	0.636	0.44	0.301	0.459	0.02
	AB	20-58	0.305	0.534	0.57	0.485	0.405	0.04
	Bt1	58-76	0.407	0.331	1.23	0.524	0.393	0.04
	Bt2	76-105	0.509	0.331	1.54	0.550	0.524	0.04

Table 8.: Percentages of Oxalate and Dithionite Extractable R_2O_2 and Active Fe and Al Ratio in profiles of Mapping Unit 2

ProfileID	Horizon	Horizon Depth	Fe(Oxal)%	Fe(DCB)%	Active Fe ratio (Fe_o/Fe_d)	Al(oxala)%	Al(DCB)%	Active Al ratio (Alo/Ald)
401	Ap	0-15	0.407	0.560	0.73	0.472	0.485	0.04
	AB	15-32	0.509	0.534	0.95	0.380	0.511	0.03
	Bt1	32-60	0.560	0.560	1.00	0.419	0.524	0.03
	Bt2	60-80	0.458	0.560	0.82	0.472	0.432	0.04
	BC	80-110	0.331	0.534	0.62	0.445	0.498	0.03
402								
	Ap	0-10	0.407	0.560	0.73	0.485	0.381	0.04
	AB	10-25	0.585	0.588	1.00	0.419	0.405	0.03
	Bt1	25-40	0.331	0.661	0.50	0.406	0.394	0.03
	Bt2	40-60	0.331	0.738	0.45	0.485	0.419	0.04
403	Ap	0-15	0.331	0.661	0.50	0.419	0.405	0.03
	AB	15-48	0.381	0.560	0.68	0.367	0.393	0.03
	Bt1	48-75	0.560	0.585	0.96	0.445	0.511	0.03
	Bt2	75-100	0.509	0.534	0.95	0.419	0.432	0.03
404	Ap	0-10	0.381	0.763	0.50	0.354	0.393	0.03
	AB	10-25	0.458	0.356	1.29	0.445	0.420	0.03
	Bt1	25-45	0.763	0.636	1.20	0.524	0.419	0.04
	Bt2	45-57	0.534	0.611	0.87	0.419	0.524	0.03
	BC	57-110	0.636	0.713	0.89	0.419	0.473	0.03

Soil Classification

The soils of the study area were classified using the Keys to Soil Taxonomy 10th Edition (Soil Survey Staff. 2006) classification guidelines. The soils were classified at the order, sub-order, great group and family levels based on specific characteristics as outlined guidelines. The soils are underlain by Coastal plain sand and the Bende- Ameki Shale formation. Soils of mapping unit 1 and 2 were classified as inceptisols . The soils generally do not have plinthite that forms a continuous phase within 30 cm of the surface.They posses an ochric epipedon with a munsell colour value of > 4(moist) and chroma of > 4 and it lacks rock structure. They also posses an underlying cambic horizon with a base saturation that is generally < 50% (by NH_4Oac) The texture of the soils is finer than loamy sand. They do not have an argilic, natric, spodic or oxic horizons and are not as recent as what can be classified as belonging to the Entisol order.

The major characteristics used in classifying the soils at the sub- order level according to Soil Taxonomy are the soil moisture regime and climate. All the profiles belong to the udic moisture regime-these are seasonally dry for 90 or more cumulative days per year, within 50 cm depth of soils. This therefore makes the soils to belong to the Udepts sub-order.

At the great group level, the parameters used in classifying the soils are mainly, base saturation, soil moisture and temperature regimes, and arrangements and degree of expression of horizons.The soils of the two mapping units have base saturation that is generally less than 50% in at least some part between 20 and 100 cm from the soil surface.Hence they were classified as Dystrudepts.

Soils of mapping unit 1 do not have any lithic, paralithic or petroferric contact within 50cm of the soil surface; they have udic moisture regime. They do not have mottles that have chroma of 2 or less within 1 m of the soil surface. They therefore belong to the sub group of Typic Dystrudepts.

For the soils of mapping unit 2, the soils generally have clayey texture.The soils have greater than 300g/kg clay content to a depth of 50cm and beyond, the soils also exhibits cracks that are wider than 1cm which extends downwards, slickensides are evident in the soils as well. These are properties shared by the Vertisols and are basis for defining vertic subgroups. These soils then qualify as having Vertic diagnostic horizon within the Soil order Inceptisol. It therefore belongs to the subgroup Vertic Dystrudepts. The soil map of the study area is a shown in Figure 3.

The results of the active ratio gave strenght to the classification. The high value of the active ratio of the oxides whic ranged between 0.33 and more than unity showed the youthfulness of the soils of the two mapping units. Oxalate and dithionite extractable Fe and Al have been used severally in soil genesis and classification. A high active ratio is an index of the youthfulness of a particular soil. They were classified as Inceptisols (Soil Taxonomy,2006).

World Reference Base (FAO/ISIC/IUSS) Classification

The soils of the study area were classified using the WRB classification system. The classification by WRB is based on soil properties defined in terms of diagnostic horizons, properties and materials, which to a great extent are measurable in the field. The diagnostic characteristics take into account their relationship with soil forming processes and at a high level are of significance for soil management (FAO, 2006).

Soils of mapping units 1 and 2 were classified as Cambisols. The profiles show little or no textural variation. They have an ochric A horizon in which the base saturation is < 50% (by NH_4Oac) . They posses a cambic B horizon having texture in the fine earth fraction of sandy loam or finer and soil structure is moderately developed and rock structure is absent in at least half the volume of the horizon. They also have an effective cation exchange capacity (sum of exchangeable bases plus exchangeable acidity in 1 *M* KCl) of less than 25 cmolc kg-1 soil. Hence the soils of the two mapping units were classified as Cambisols. Mapping unit 1 as classified at the lower level as Dystric Cambisol while mapping unit 2 was classified as Vertic cambisol.

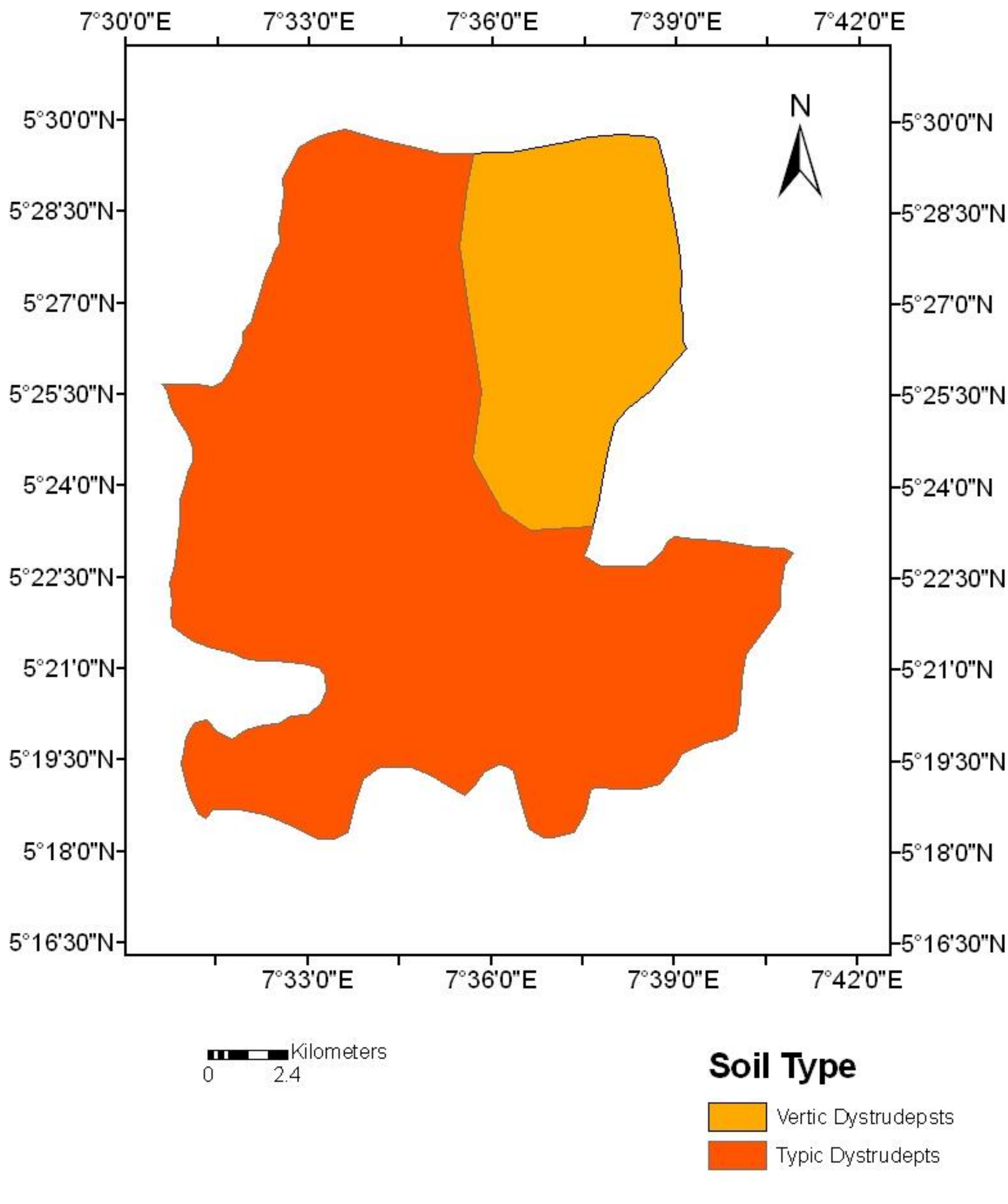

Figure 4. : Soil Map of Ikwuano LGA, Abia State

Series Classification

Series classification was done using Moss (1957) as modified by Ogunkunle (1983) and Ojanuga (1998) , classification of soils on sedimentary materials. At the series level the soils belong to Kulfo(Orlu) and Ahiara series using (Moss,1957) as modified by Ojanuga.

Ahiara Series

The soils in this series are essentially reddish deep sands with brownish upper layers, with little or no increase in texture down the profile. They occur in association with Kulfo and Alagba series but they are sandier than the latter and typically contain no gravel ,stones or concretions. This series is typified by soils of mapping unit 1, where the texture is sandy loam at the upper layer.

Kulfo Series (Clayey sub series). Soils in this series are typified by soils of mapping unit 2 . These soils are essentially those with brownish sandy or very sandy upper layers passing down into brownish-red sandy clay. The clay value of the soils ranged from 400g/kg at the surface to 610g/kg in the sub surface. The morphological properties of soils of this mapping unit (described above) fits into the diagnostic characteristics given by Moss (1957). They occur typically in sloping upper and middle slope sites. The soils occur in areas of gently to stongly undulating relief and often occur in association with disintegrating ironstone or laterite.

The general practice for correcting soil acidity and nutrient deficiency especially of P is by lime and P fertilizer application.Intercropping systems using landraces legumes, the use of sawdust ash are also methods which can be adopted in ameliorating acidic soils(Ibeawuchi, 2007; Awodun,2007) The use of on-farm generated organic fertilizers can be a good means for a sustainable agriculture on the studied soils. Also the use of P-efficient and acid-tolerant cultivars can be adopted, thus reducing the need for expensive input. The soil fertility can also be improved and maintained through the addition of crop residues, manure and compost. Mulching practices will also help to reduce soil erosion and ultimately increase the soil fertility. The most effective way to maintain soil fertility, soil structure and biological activity is to provide enough soil organic matter, or soil organic carbon pools, in the soils (Chen and Hseu, 1997). Soil amendment with compost may enhance soil organic matter level, biological activities and physical condition for increased productivity (Babalola et al, 2012). Poultry manure and cocoa pod ash can also be used to fertilize soil for crop production (Ayeni and Adeleye, 2012). Nutrients exported from the soil through harvested biomass or lost from soil by gaseous loss, leaching, or erosion must be replaced with nutrients from external sourcesAgricultural practices such as incorporation of crop residues have a direct impact on soil health and productivity.(Hameeda et al ,2006) Agroforestry is recommended as a soil-protecting alternative to shifting cultivation to achieve higher yields without requiring expensive inputs. Cambisols, although less fertile, can be used for mixed arable farming and as grazing and forest land. Those occuring on steep slopes are best kept under forest. Undemanding acidity tolerant cash crops such as pineapple, cashew, tea and rubber can be grown with some success. Increasing areas of acid soils are planted to oil-palm (e.g. in Malaysia and on Sumatra. Most of the tree roots are concentrated in the humous surface horizon with only a few tap-roots extending down into the subsoil. Cambisols are suitable for production of rainfed and irrigated crops only after liming and full fertilization. Rotation of annual crops with improved pasture maintains the organic matter content. A good fertility management strategy might be the introduction of Mycorrhiza symbiosis which is effective on such soils especially with root crops which is a common crop in the study area, thus reducing the P requirement for crop production.

CONCLUSION

Results from this study show that the soils belong to the soil order Inceptisol in Soil Taxonomy system, which is Cambisol in the World Reference Base classification system. The soils are acidic and of low fertility status. Hence the major management problems of the soils which are relevant to agricultural production are those related to soil liming requirement and the maintenance of soil fertility under continuous cropping. The productivity of the soils can be improved through the judicious use of organic and inorganic fertilizers.

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