Journal of Agriculture, Environmental Resource and
Management
ISSN2245-1800(paper) ISSN 2245-2943(online)
5(4)607-613; Dec.2021; pp1029-1046

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Effective and Efficient Utilization of some 'Typic Endoaquepts' backswamp hydric soils in the Yenagoa area of Bayelsa State, Southern Nigeria for Sustainable Agricultural Productivity

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Abstract

This research was conducted in Okolobiri-Gbarain, Akaibiri-Ekpetiama, Epie-Zarama, Ikarama-Okordia and Tein-Biseni in the Yenagoa Local Government Area of Bayelsa State, Niger Delta, Southern Nigeria to ascertain the agricultural potentials of the soils of the backswamp (‘Typic Endoaquepts’). Five profile pits (OG4, AE4, EZ4, IO4 and TB4) one each were sited in the backswamp of the study sites. Soils samples were collected from identified pedogenic horizons of the profiles for laboratory analysis. Morphological properties were examined insitu under moist soil conditions. Physical and chemical characteristics such as bulk density varied from 1.30g/cm^3 – 1.70g/cm^3; particle density, 2.31g/cm^3 – 2.65g/cm^3; total porosity, 1.00% - 34.00%; silt, 10.00% - 48.00%; clay 38.00% - 82.00%; soil pH, 5.01 – 6.40 (moderately – slightly acidic); total nitrogen, 0.05% - 0.24% (low – medium); organic carbon, 0.12% -2.34% (very low – medium); organic matter, 0.21% - 4.05% (very low – moderate); available phosphorus, 0.12µg/g - 3.15ug/g (low); exchangeable potassium, 0.05cmol/kg- 0.37cmol/kg (very low – moderate); exchangeable sodium, 0.02cmol/kg – 0.04cmol/kg (very low); exchangeable calcium, 4.00cml/kg -11.70cmol/kg (low – high); exchangeable magnesium, 1.12cmol/kg – 3.12cmol/kg (moderate); cation exchange capacity, 13.40cmol/kg – 24.51cmol/kg (high); base saturation, 77% - 94% (high – very high); exchangeable sodium percentage, 0.10% - 0.36% (very low). The soils are deep and fertile but very poorly drained. They are classified into the order ‘Inceptisol’; suborder, ‘Aquepts’; great group, ‘Endoaquepts’; subgroup, ‘Typic Endoaquepts’ (USDA) and Eutric Gleysol (WRB). Integrated soil management practices such as drainage will make these soils more available for cultivation thus stimulating higher agricultural productivity.

Keywords: Backswamp, ‘Typic Endoaquepts’, Eutric Gleysol, pedogenic, ‘Inceptisol’, Integrated

INTRODUCTION

The 2020 population estimate of Nigeria according to the Nigerian Bureau of Statistics was over 206 million (NBS, 2020). This implies that the population of Nigeria is growing at a very fast rate and there is the urgent need to adequately cater for this fast growing population. In the 2020 global hunger index, Nigeria was ranked 98th out of 107 countries that was evaluated. It scored 29.2 based on set of data and information used (GHI, 2020). To nip hunger on the bud and to create a robust economy to take care of the fast growing population, the agricultural sector needs cardinal attention. The need to adequately harness our land resources therefore becomes imperative. According to Okusami (2003) a contributory factor of low food production in Nigeria is the ratio of used to un-used available land in Nigeria especially hydric soils with hydromorphic properties. Nigeria is blessed with abundant agro-ecological resources and diversity but it has become one of the largest food importers in sub-Saharan Africa (Idachaba, 2009). Any system where food demand is not sufficiently marched by supply is no doubt one with looming food crisis (Ojo et al., 2012).

According to Babalola et al. (2011), hydromorphic wetland or hydric soils show a wide variation in natural fertility in Nigeria and are potentially very useful for agricultural production, however they are grossly under-utilized. The under-utilization of the Niger Delta coastal and swampy soils may be attributed to lack of understanding of the agricultural potentials of these soils and lack of developed technology for effective management of the flooded soils (Imogie et al., 2012).

Soil survey staff (2014) classified ‘Typic Endoaquepts’ as having aquic moisture regime and are flooded at some point wholly or partially in a year. The ‘Typic Endoaquepts’ largely represents the backswamp soils of the study area which is part of the meander belt of the Niger Delta and are least used agriculturally.

The aim of this study is to evaluate the agricultural potentials of the hitherto under-utilized backswamps by examining their characteristics for crop production in other to mitigate the crushing effects of insufficient food production (hungry).

MATERIALS AND METHOD

Site Description

The study was conducted in Okolobiri, Akaibiri, Epie, Ikarama and Tein in the Yenagoa Local Government Area of Bayelsa State in the meander belt of the Niger Delta of southern Nigeria. The study area is located in the equatorial monsoon climate (fresh water rain forest zone) and is located between latitudes 04° 50’ 49.20” and 05° 23’ 21.8” N of the equator and longitudes 006° 12’ 22.6” and 006° 34’ 00.3” E of the Greenwich meridian. It covers 49,881 hectares with a pronounced rainy season characterized by high air temperatures throughout the year. Dry and wet season were distinctly separated. The former starts from November to February and the later from March to October, however, during March and April, rainfall increased and the highest rainfall was experienced during July to September decreasing sharply in October with average rainfall of 2539mm per annum and temperature range of 29ºC to 32ºC and relative humidity varying from 81% to 87% largely depending on the prevailing season and the evaporation from the many creeks and flood water.

Field Studies

The study area was identified and the backswamp mapping units were delineated based on vegetation, topography, soil types, drainage condition, textures and structures. One soil profile pit (pedon) each with specifications of 2m x 1m x2m (length width and depth) was sunk in the five study locations between March and April 2015. Soil samples were taken from identified pedogenic horizons and was described according to the FAO procedure. Undisturbed core samples were also taken for bulk density analysis. A hand held GPS (global positioning system) was used to determine the coordinates were the profile pits were sited. Standardized munsell colour chart was used for the description of the soil colour.

Laboratory Analysis

Soil samples taken from the pedogenic horizons of the profile pits were air dried for five (5) days, crushed and sieved with a 2mm mesh sieve (samples were clearly marked and taken to the laboratory for routine soil analysis procedures for the determination of the physico-chemical properties/characteristics of the soils.

Soil particle size distribution was determined using the hydrometer method of Bouyoucous (1951) as described by Gee and Or (2002). Bulk density was determined by the core method of Grossman and Reinsch (2002) and calculated as the weight of the soils divided by the volume of the soil sample. Particle density was determined by the pycnometer method of Black (1965). Total porosity was calculated from particle and bulk density. Soil reaction (soil pH) was determined using the procedure of Van Reeuwijk (2002) using glass electrode pH meter. Organic carbon was determined using the dichromate wet oxidation method of Walkley and Black as described by Van Reeuwijk (2002). Organic matter was determined by multiplying the percentage of organic carbon by 1.729 (Van Bemmelen factor). Total nitrogen was determined by the macro-Kjeldahl digestion method as described by Van Reeuwijk (2002). Available phosphorus determined by using the molybdenum blue Bray and Kurtz No2 method (IM NH_4OA_c) as described by Olsen and Sommers (1990) buffered at 7.0. Exchangeable cations Ca, Mg, Na, K) was determined by extracting with neutral ammonium acetate (IM NH_4OA_c) buffered at 7.0. Exchangeable Ca and Mg in the IM NH4 OAc leachate was determined by EDTA titration method of Black (1965) as described by Thomas (1982). Exchangeable Na and K in the leachate was determined by flame photometry. Total exchangeable based was determined by summing up the exchangeable basic cations and exchange acidity (Brady and Weil, 2002). Percentage base saturation was calculated as the percentage of exchangeable bases divided by ECEC. Aluminum saturation was calculated as the percentage of exchangeable aluminum divided by the effective cation exchange capacity. Exchangeable acidity was determined by titration method (Juo, 1979). ESP was calculated as the percentage of exchangeable sodium divided by ECEC. Electrical conductivity was determined using conductivity meter in soil water extract (Rowell, 1994).

Soil Classification

Soil classification was done based on the results obtained from the laboratory analysis and field morphological properties, the soils were classified according to soil taxonomy (soil survey staff, (2014) and correlated with WRB (2014).

Results and Discussion

Table 1 showed the morphological properties of the soils and legend for Table 1 describes the morphological properties. Profile pits (pedons) OG4 (located in Okolobiri-Gbarain), AE4 (located in Akaibiri–Ekpetiama), EZ4 (located in Epie-Zarama), IO4 (located in Ikarama-Okordia) and TB4 (located in Tein-Biseni) represented soils of the very poorly drained backswwamp. The colour of the soils OG4, AE4, EZ4, IO4 and TB4 varied from dark brown (10 YR 3/4) to dull yellowish orange (10 YR 7/2). The colour of the mottles of the soils varied from many, coarse, prominent, dark brown (10YR 3/4) to many, coarse, prominent yellowish brown (10 YR 5/6). The texture of the soils varied from silty clay, clay loam to clay while the structure varied from weak, fine, angular blocky to strong, medium, subangular blocky. The consistence of the soils varied from hard/firm/sticky, plastic; very hard/very firm/stickly, plastic to extremely hard/extremely firm/very sticky, very plastic. There were abundant medium roots on all the surface horizons while the outline of the horizons within the pedons varied from clear wavy, clear smooth, gradual smooth, abrupt wavy, diffuse broken, diffuse wavy and diffuse smooth. Earthworm activities with few mica flakes were seen in the surface horizons and few to many mica flakes were seen in the subsurface horizons of the soils.

The diagnostic surface horizon for the soils were ochric epipedon, while subsurface horizon were cambic. Water table was encountered in pedons EZ4, IO4 and TB4 and measured 0-100 cm while water table was not encountered in pedons OG4 and AE4.

Colour of the soils were darker in the surface horizon than the subsurface horizon in all the pedons. The darker colour of the surface horizons were mainly the result of organic matter coatings of the mineral grains which is the effect of higher organic matter contents in the surface horizons. Colour constitutes a prominent place in soil classification, soils that are well drained had redder hues and higher chromas while poorly drained soils had yellower hues. Dengiz *et al*. (2012) also attributed darker colours of the surface horizon to organic matter coatings. The grayness of the soils suggested that the moisture regime included longer periods of saturation. This agreed with earlier findings of Ayolagha, (2001) and Egbuchua and Ojeifo, (2007).

Mottling was distinct in the soils, this was due to the texture and drainage pattern of the area, mottling is an indication of the internal drainage pattern of the soils and is associated with the reduction and mobilization of iron and manganese and their subsequent oxidation and precipitation which can be attributed to the seasonal fluctuating ground water table or the intermittent presence of a perched water table. This agreed with the earlier findings of Clothier et al. (1978).

The textures of the soils were finer which were clayey or silty clay and the consistence of the soils were friable, firm and extremely firm. This may be due to the textural composition of these soils as a result of the cohesion and adhesion forces acting on the soil materials. This agreed with the findings of Adamu, (2016). **Physical Properties**

Table 2 showed the physical properties of the soils. The bulk density of the soils ranged from 1.30g/cm^3 to 1.70g/cm with mean values of 1.60g/cm^3, 1.54g/cm^3 1.37g/cm^3, 1.38g/cm and 1.53g/cm3 for pedons OG4, AE4, EZ4, IO4 and TB4, respectively. The surface horizon had lower bulk density values. This might be as a result of the higher organic matter content recorded and the impacted nature of the surface horizons of the soils being recent alluvium. This agrees with the findings of Ayolagha, (2001) and Egbuchua and Ojeifo (2007). There was an increase in bulk density with increase in depth in all the pedons. This might have been due to compaction which resulted from over burden and less organic matter content down the pedon. This agreed with the findings of Egbuchua *et al.* (2012), Adamu (2016), Ogban and Ekerette (2001), Onweremadu *et al.* (2007) and Njoku *et al.* (2019). The high bulk density of the backswamp can also be attributed to the highly compacted nature because of the presence of more clay content.

The particle density of the soils ranged from 2.31g/cm^3 to 2.62g/cm^3 with mean values of 2.52g/cm^3, 2.54g/cm^3, 2.39g/cm^3, 2.40 g/cm^3 and 2.53 g/cm^3 for pedons OG4, AE4, EZ4, IO4 and TB4, respectively. Particle density increased with depth in all the soils, the surface horizons had lower particle density. This may be attributed to the presence of organic matter content in the surface horizons which agreed with the findings of Alem (2014). The mean values of the particle density in the study area showed that quartz, feldspar, micas and other silicate, clay minerals were major constituents of the mineral portions of the soils since the values are closely related to the minerals. This view was also held by Mordi (1986) and Kamalu (2011).

The total porosity of the soils ranged from 35.00% to 44.00% with mean values of 37.00%, 39.00%, 43.00%, 43.00% and 40.00% for pedons OG4, AE4, EZ4, IO4 and TB4, respectively. Total porosity values were generally higher in the surface horizons than the subsurface horizons. This is attributed to presence of organic matter and lower bulk densities recorded in the surface horizons. This agreed with the findings of Ayolagha and Onuegbu (2002). The mean values of the pedons showed that the soils were generally satisfactory soils (pedons EZ4, IO4 and TB4) while pedons OG4, AE4 were unsatisfactory. According to Kachinkii (1965), best soils should have porosities of over 50%, good soils should have between 45%-50%, satisfactory soils should have between 40%-45%, unsatisfactory soils under 40% and poor soils should be below 30%. The soils had moderate values of silt using Hazelton and Murphy (2007) standard and could be attributed to constant fluvial deposits and sedimentation process that occurred in the soils. This was consistent with the findings of Egbuchua *et al* (2011). The soils had high clay content using Hazelton and Murphy (2007) standards and it increased down the horizons. This may be attributed to the presence of eluviations and illuviation processes or translocation within the pedons. It agrees with the findings of Nahusenay, (2015). The mean values of silt/clay ratio of all the pedons of the soils were above 0.15 indicating them as soils made up of young parent materials with low degree of weathering. This agreed with the findings of Fasina *et al*. (2015).

Chemical Characteristics

Table 3 showed the chemical characteristics of the soils. The pH of the soils varied from 5.01-6.40 (moderately to slightly acidic) and were irregularly distributed down the pedons. The pH values were lower in the surface horizons and this might to be attributed to the production of organic acids by decomposing organic matter as earlier alluded to by Dickson *et al*. (1998). The lower pH of the soils may also be attributed to the finer texture of the soils which easily bind exchangeable H and Al onto their exchange sites. This agreed with the findings of soil survey staff (1951), that soils rich in clay or organic matter had greater reserves of acidity. The lower mean values of pH of soils could also be attributed to the redox products of ferrolysis that is associated with wetland soils (Egbuchua *et al.*, 2011). The pH of the soil falls within the suitable range of production of most crops. The range is closely related to the range of 5.5 to 6.5 proposed by Ajiboye, (2012) and 5.5 to 7.0 proposed by Chude *et al.* (2011) and Sasseville (2013), as suitable for thriving of most crops as soil nutrients will be readily available for absorption by plants at this pH range. The soils studied showed that ΔpH (pH in H_2O to pH in KCl) values were positive (the soil pH in KCl were lower than the pH in H_2O. This indicates the presence of net negative charge on colloidal particles of the exchange site. This agreed with the findings of Papiernick *et al.* (2007). The total nitrogen values of the soil ranged from 0.05% to 0.24% which indicates that the soils have low to medium total nitrogen according to the ratings of Tekalign (1991). The soils had higher total nitrogen in the surface than the subsurface soils, however, they were generally low. The higher total nitrogen of the surface horizons might be attributed to organic matter content. All the total nitrogen mean values of the pedons were below the critical level of 0.15% reported by Ibia (1995). Organic carbon values ranged from 0.12% to 2.34% which indicates that the soils had very low to medium organic carbon content according to the ratings of Tekalign (1991). The organic carbon content in the soils decreased with depth, same trend with total nitrogen. The higher organic carbon content recorded in the surface horizons might be attributed to low rate of mineralization of organic matter. This findings agreed with that of Egbuchua (2011). Organic matter content ranged from 0.21% to 4.05% (very low to moderate). The organic matter content takes the same trend as that of total nitrogen and organic carbon. The higher values of organic matter in the surface horizon were due to the slow rate of mineralization of organic materials as a result of the prolonged waterlogged conditions after the submergence cycle. The findings agreed with that of Adamu (2016). The available phosphorus ranged from 0.12µg/g to 3.15µg/g (low). The lower content of available phosphorus in the soils might be due to their higher percentage of clay and aquic moisture regime. The higher phosphorus values in the topsoil might be due to biocycling of available phosphorus and influence of organic matter. This agreed with the findings of Udo (2001) and Egbucha and Ojeifo (2007). The C:N ratio of the surface horizons were around ten (10) and above which suggest satisfactory conditions for normal microbial activity and humus decomposition. A C:N ratio of around ten (10) was also suggested by Hadas *et al.* (2004) as satisfactory conditions for normal microbial activity and humus decomposition.

The exchangeable basic cations (Ca, Mg, Na, K) in the soils were low to high except Na (sodium) that was low, based on FAO (2006) ratings, calcium ranged from 4.00cmol/kg to 11.70cmol/kg, Magnesium from 1.12cmol/kg to 3.12cmol/kg, potassium from 0.05cmol/kg to 0.37cmol/kg and sodium 0.02cmol/kg to 0.04cmol/kg. The mean values of all the pedons of the soils were above the critical values of 4.0cmol/kg (FPDD, 1990) for calcium; 0.5cmol/kg (Ibia, 1995) for Magnesium; while the mean values of pedons EZ4 and IO4 were above the critical values of 0.2cmol/kg (FPDD, 1990). The mean values of all the pedons were below the critical value of 0.2cmol/kg (Ibia, 1995) for sodium. The low sodium content of the soils makes them non-sodic and it disagreed with the findings of Esu (1991) which reported high Na contents in alluvial soils. The soils have relatively higher clay content with higher exchangeable basic cations which might be attributed to the capacity of these soils to retain basic cations.

The cation exchange capacity of the soils ranged from 13.40cmol/kg to 24.51cmol/kg. According to the ratings of Esu (1991), the soils had high CEC. There was irregularities in the values of CEC down all the pedons. The high CEC of the soils might be attributed to the presence of 2:1 clay minerals in the clay fraction and the fairly high clay and organic matter content. The irregularities in values of CEC down the depth of the pedons might be due to the heterogeneous nature of the parent materials, as also adduced by Mordi (1986), and Alem, (2014).

The percentage base saturation (BS) values of the soil varied from 77% to 94% which according to the ratings of Esu (1991), is high to very high. The high base saturation of these soils might be attributed to the origin and recentenss of the alluvial parent materials that form the soils which may be indicative of the presence of weatherable soil minerals. The values of base saturation in all the horizons in the pedons of the soils were above the critical value of 60% (Landon, 1991), indicating that the soils had high potential fertility

Soil Classification

Table 4 showed the classification of the soils. The soils were classified into the order 'inceptisol' because of the presence of ochric epipedon and subsurface cambic horizon suborder 'Aquepts' because of the 'Aquic moisture regime and the warmer iso-hyperthermic temperature regime and into the great group 'Endoaquepts' and subgroup 'Typic Endoaquepts' because of their high base saturation (SSS, 2014). Using the World Reference Base (WRB), (2014), the soils were classified as 'Eutric Gleysol' because of their high base saturation in the various horizons and hydromorphic properties (the presence of distinct mottles). This confirms the observations of Ayolagha (2001), Kosuowei (2008) and Wenibo (2012) that the most prevalent soils of the meander belt were 'Inceptisols'.

Conclusion

The under-utilized backswamp – 'Typic Endoaquepts' hydric soils has been showed to be highly fertile based on the study. It can be cultivated for crop production in the dry season. The good soil texture, high percentage base saturation (BS), high cation exchange capacity (CEC) of these soils are very desirable in agricultural soils, because it denotes greater availability of some basic and ammonium ions, which are important macro and secondary plant nutrients for sustainability of crops/plants.

The main values of exchangeable calcium and magnesium values of the soils were all above the critical levels required for the cultivation of crops. It serves as a yardstick for the determination of the agricultural suitability of the soils for crop production. The soils were alluvial in nature with young parent materials which are silt laden due to the annual flooding cycle. The silt deposited on these soils has high fertilizing effects and as such can be used for dry season farming for efficient agricultural productivity.

However, the soils are very poorly drained and thus need integrated sustainable management practices, such as surface and subsurface drainage, ridges, furrow, broad banks for effective and efficient cultivation.

The effective and efficient use of the hitherto under-utilized backswamp hydric soils for dry season farming will increase the ratio of used land as against unused land. This will eventually contribute to availability of sufficient food, thus reducing hunger.

Table 1: Morphological Properties of the Soils of the Study AreaSoils of the Backswamp

							Consistence				
Horizon	**Depth (cm)**	**Colour (Moist)**	**Mottles**	**Texture**	**Structure**	**Dry**	**Moist**	**Wet**	**Roots**	**Boundary**	**Remark**
					OG4						
A	0 -25	10 YR 4/4	10 YR 5/6,c2d	SiC	2, fabk	Vh	mrfi	s, p	Abundant	cw	Abundant medium roots/ earthworm cast/activities
Bw1	20 -45	10 YR 5/1	10 YR 4/6, m2d	SiC	2, mabk	h	mfi	s, p	Abundant	cw	Few fine mica flakes
Bw2	45-70	10 YR 6/1	10 YR 5/6, m2p	C	2,msbk	h	mfi	s, p	Few	gs	Few fine mica flakes
Bwg1	70-105	10 YR 7/2	10 YR 3/4, m2p	C	3, msbk	vh	mrfi	s, p	Few	aw	Many fine mica flakes
2Bwg1	105 -150	10 YR 5/3	10 YR 4/4, m2p	C	3, msbk	eh	mefi	vs, vp	Few	db	Dark greyish and brown iro concretions
2Bg1	150 -200	10 YR 5/1	10 YR 3/4, m3p	C	3,msbk	eh	mefi	vs, vp	v. few		Few fine mica flakes
					AE4						
A	0 -15	10 YR3/4	10 YR 4/6, f1f	SiC	2, mabk	h	mfi	s, p	Abundant	gs	Earthworm activities (pron
AB	15 -30	10 YR 4/2	10 YR 5/6, m3d	C	2,msbk	vh	mefi	s, p	Abundant	cw	Few fine mica flakes
Bwg1	30-60	10 YR 5/1	10 YR 3/4, m3p	C	2,msbk	vh	mefi	s, p	Abundant	dw	Few fine mica flakes
Bwg2	60-100	10 YR 6/1	10 YR 5/6, m2p	C	2,msbk	eh	mefi	vs, vp	Few	ds	Many fine mica flakes
2Bwg1	100 -145	10 YR 7/1	10 YR 3/4, m2p	C	3,msbk	eh	mefi	vs, vp	Few	db	Many fine mica flakes
2Bg1	145 -200	10 YR 6/2	10 YR 5/6, m3p	C	3,msbk	eh	mefi	vs, vp	v. few		Few fine mica flakes
					EZ4						

A	0 -15	10 YR 4/4	10 YR 4/6, c1f	SiC	2, fabk	h	mfi	s, p	Abundant	cw	Abundant medium roots/ earthworm activities
Bwg	15-30	10 YR 5/3	10 YR 4/4, m2d	SiC	1, fabk	h	mfi	s, p	Abundant	cw	Few fine mica flakes
Bg1	30-65	10 YR 5/1	10 YR 3/4, m2p	SiC	1, fabk	vh	mefi	s, pp	Abundant	gs	Many fine mica flakes
2Bg1	65-80	10 YR 5/2	10 YR 3/4, m2p	C	2,msbk	eh	mefi	vs, vp	Few	db	Dark brown iron concretio
2Bg2	80 -100	10 YR 5/1	10 YR 3/4, m2p	C	2, msbk	eh	mefi	vs, vp	v. few		Few fine mica flakes
					IO4						
A	0-20	10 YR 4/4	10 YR 3/4, m2p	SiC	2, fsbk	vh	mvfi	s, p	Abundant	gs	Abundant medium roots/eart5hworm activities
Bwg1	20-35	10 YR 4/6	10 YR 4/6, m1f	SiC	3, mabk	h	mfi	s, p	Abundant	cw	Few mica flakes
Bwg2	35-52	10 YR 5/3	10 YR 6/6, m2d	C	2, msbk	h	mfi	s, p	Abundant	dw	Dark brown manganese no
Bg1	52-70	10 YR 6/2	10 YR 4/6, c2d	C	2, msbk	eh	mefi	vs, vp	Few	db	Dark brown iron concretio
2Bg1	70-100	10 YR 7/2	10 YR 5/6, m2p	C	3, msbk	eh	mefi	vs, v	v. few	gs	Few fine mica flakes
					TB4						
A	0-8	10 YR 4/4	10 YR 5/4, c2f	CL	1, mabk	h	mfi	s, p	Abundant	cw	Abundant medium roots/earthworm cast/activi
Bwg1	8-20	10 YR 4/6	10 YR 3/4, c2d	CL	2, mabk	h	mfi	s, p	Abundant	dw	Abundant medium roots/earthworm cast/activi
Bg	20-35	10 YR 5/3	10 YR 4/4, m2d	CL	2, mabk	vh	mvfi	s, p	Abundant	ds	Few fine mica flakes
2Bg1	35-60	10 YR 6/2	10 YR 5/4, m2d	C	2, msbk	vh	mvfi	s, p	Few		Dark brown iron concretio
2Bg2	60-100	10 YR 7/2	10 YR 3/4, m2p	C	3, msbk	eh	mefi	vs, vp	Few		Few fine mica flakes

Key

Source: Field Survey

Legend for Table 1

Mottling

Abundance
Few……...f
Common…………...c
Many……………….m

Size
Fine…………1
Medium….2
Coarse………3

Contrast
Faint……………f
Distinct………. d
Prominent……. p

Texture

Sandy loam……………SL
Loamy Sand…………LS
Sandy clay loam…SCL
Loam…………………. L
Clay loam………….CL

Clay Loam………...CL
Silty clay loam…...SiCL
Silty clay……………...SiC
Clay………………………C
Sandy clay…………...SC

Structure

Size:
Very fine……vf
Fine……………f
Medium…….m
Coarse……….c

Grade **Type:**

Structureless…………0
Weak……………………1
Moderate…………….2
Strong…………………3

Angular work………...abk
Subangular blocky…. sbk
Granular…………………gr
Single grain…………….sg

Consistence Massive…………………m

Moist SoilWet SoilDry soil

Loose………………...ml
Very friable………...mvfr
Friable…………………. mfr
Firm………………………. mfi
Very firm…………………mvfi
Extremely firm…………mefi

Non sticky…………………. ns
Non plastic………………np
Slightly sticky………………ss
Sticky………………………. s
Slightly plastic…………. sp
Very sticky………………vs

Soft…………………. s
Loose………………...l
Hard………………….h
Very hard…………. vh
Extremely hard…eh

Boundary

Distinctness
Abrupt- a: clear-c: gradual-g: diffuse-d
Topography
Smooth-s: wavy- w: irregular- l: broken-b

All symbols used here confirm with that of soil survey manual USDA Handbook No. 18pp 139- 140 1951

Table 2: Physical Properties of Soils of the Study Area Soils of the Backswamp

					← Particle Size Distribution →				
Horizon	**Depth (cm)**	**Bulk Density (g/cm^3)**	**Particle Density (g/cm^3)**	**Total Porosity (%)**	**Sand** 2-0.05mm	**Silt** 0.05-0.002mm	**Clay** < 0.002mm	**Silt/Clay Ratio**	**Textural Class**
				OG4					
A	0-20	1.48	2.44	39.00	16.00	43.00	41.00	1.05	Silty clay
Bw1	20-45	1.52	2.45	38.00	15.00	44.00	41.00	1.07	Silty clay
Bw2	45-70	1.60	2.50	36.00	34.00	23.00	43.00	0.53	Clay
Bwg1	70-105	1.62	2.55	36.00	28.00	25.00	47.00	0.53	Clay
2Bwg1	105-150	1.65	2.58	36.00	28.00	23.00	49.00	0.47	Clay
2Bg1	150-200	1.70	2.62	35.00	32.00	17.00	51.00	0.33	Clay
	Mean	1.60	2.52	37.00	25.50	29.17	45.33	0.66	
				AE4					
A.	0-15	1.42	2.40	41.00	10.00	48.00	42.00	1.14	Silty clay
AB	15-30	1.50	2.46	39.00	15.00	30.00	55.00	0.55	Clay
Bwg1	30-60	1.50	2.50	40.00	17.00	20.00	63.00	0.32	Clay
Bwg2	60-100	1.58	2.60	39.00	12.00	22.00	66.00	0.33	Clay
2Bwg1	100-145	1.60	2.60	38.00	5.00	20.00	75.00	0.27	Clay
2Bg1	145-200	1.65	2.65	38.00	3.00	15.00	82.00	0.18	Clay

	Mean	1.54	2.54	39.00	10.33	25.83	63.84	0.47	
				EZ4					
A	0-15	1.31	2.31	43.00	5.00	41.00	54.00	0.76	Silty clay
Bwg	15-30	1.34	2.37	43.00	8.00	36.00	56.00	0.64	Silty clay
Bg1	30-65	1.38	2.40	42.00	3.00	41.00	56.00	0.73	Silty clay
2Bg1	65-80	1.40	2.41	42.00	1.00	19.00	80.00	0.24	Clay
2Bg2	80-100	1.42	2.44	42.00	1.00	17.00	82.00	0.20	Clay
	Mean	1.37	2.39	43.00	3.60	30.80	65.60	0.51	
				IO4					
A	0-20	1.30	2.31	44.00	6.00	40.00	54.00	0.74	Silty clay
Bwg1	20-35	1.35	2.40	44.00	7.00	35.00	58.00	0.60	Silty clay
Bwg2	35-52	1.40	2.41	42.00	18.00	20.00	62.00	0.32	Clay
Bg1	52-70	1.40	2.42	42.00	14.00	13.00	73.00	0.18	Clay
2Bg1	70-100	1.43	2.45	42.00	14.00	10.00	76.00	0.23	Clay
	Mean	1.38	2.40	43.00	11.80	23.60	64.60	0.41	
				TB4					
A.	0-8	1.40.	2.41	42.00	26.00	36.00	38.00	0.95	Clay loam
Bwg1	8-20	1.45	2.50	42.00	25.00	37.00	38.00	0.97	Clay loam
Bg	20-35	1.52	2.52	40.00	28.00	33.00	39.00	0.85	Clay loam
2Bg1	35-60	1.60	2.58	38.00	22.00	37.00	41.00	0.90	Clay

2Bg2	60-100	1.68	2.62	36.00	17.00	10.00	63.00	0.16	Clay
	Mean	1.53	2.53	40.00	23.60	32.60	43.80	0.77	

OG4 = Okolobiri Gbarain,AE4 = Akaibiri Ekpetiama, EZ4 = Epie Zarama,I04 = Ikarama Okordia, TB4 = Tein Biseni

Table 3: Chemical Characteristics of Soil of the Study AreaSoils of the Backswamp

Horizon	Depth (cm)	Soil pH in H_2O 1:2.5	Soil pH in KCl 1:1	T.N (%)	O.C(%)	O.M (%)	Avail P. (µg.g}	C/N ratio	Exchangeable cations (Cmol/kg)				TEB (cmol/kg)	EA (Cmol/Kg)	CEC (Cmol/Kg)	ECEC (Cmol/kg)	% BS	Exch. H (Cmol/Kg)	Exch. AL (Cmol/Kg)	AL Sat. (%)	ESP (%)	EC (µS/cm)
									K^+	Na^+	Ca^{2+}	Mg^{2+}										
											OG 4											
A	0-12	5.01	4.36	0.20	2.12	3.67	0.91	10.60	0.09	0.02	5.30	1.67	7.08	1.92	15.02	9.00	79	0.64	1.28	14.22	0.18	30.70
Bw1	12-35	5.78	4.98	0.11	1.42	2.46	0.98	8.88	0.11	0.02	7.70	4.67	12.50	2.20	20.11	14.70	85	0.56	1.64	11.16	0.43	21.70
Bw2	35-65	5.78	5.22	0.12	1.22	2.11	3.15	10.17	0.10	0.02	10.40	6.83	17.35	2.32	24.20	19.67	88	0.68	1.64	8.34	0.10	22.30
Bwg1	65-97	5.71	5.11	0.10	1.04	1.80	0.98	10.40	0.11	0.02	10.30	5.17	15.60	1.24	20.73	16.54	93	0.16	1.08	8.41	0.11	20.30
2Bwg1	97-142	5.95	5.20	0.06	0.84	1.45	0.84	14.00	0.16	0.03	11.70	5.67	17.56	1.17	20.16	18.73	94	0.19	0.98	5.23	0.16	22.10
2Bg1	142-200	6.16	5.30	0.05	0.65	1.12	0.49	13.00	0.15	0.02	10.70	6.70	17.57	1.24	21.24	18.81	93	0.32	0.92	4.89	0.11	25.20
	Mean	**5.77**	**5.03**	**0.12**	**1.22**	**2.10**	**1.23**	**11.18**	**0.12**	**0.02**	**9.35**	**5.12**	**14.61**	**1.68**	**20.24**	**16.29**	**89**	**0.43**	**1.26**	**8.38**	**0.13**	**23.72**
											AE4											
A	0-15	6.06	5/37	0.18	1.84	3.18	0.21	10.22	0.06	0.02	9.30	5.33	14.71	1.12	18.11	15.82	92	0.10	1.02	6.44	0.13	20.80
AB	15-30	6.30	5.50	0.16	1.64	2.84	1.61	10.25	0.06	0.02	10.30	5.03	16.21	1.52	22.40	17.73	91	0.64	0.88	4.96	0.11	18.20
Bwg1	30-60	6.15	5.34	0.12	1.58	2.73	0.96	13.17	0.05	0.02	10.00	6.50	15.58	2.30	20.32	17.88	87	0.50	1.80	10.07	0.17	18.00
Bwg2	60-100	5.95	5.02	0.10	1.56	2.70	0.85	15.60	0.05	0.02	10.35	6.00	16.42	2.84	23.21	19.26	85	0.64	2.20	0.10	0.10	17.30
2Bwg1	100-145	5.90	5.00	0.07	0.91	1.57	0.55	13.00	0.12	0.02	11.10	5.85	17.09	3.12	22.58	20.21	85	0.27	2.85	0.10	0.10	14.40

2Bg1	145-200	6.04	5.30	0.05	0.86	1.49	0.44	17.20	0.16	0.04	10.07	6.65	16.87	2.92	24.51	19.79	85	0.27	2.65	0.20	0.20	16.50
	Mean	**6.07**	**5.26**	**0.11**	**1.40**	**2.42**	**0.77**	**13.24**	**0.08**	**0.03**	**10.18**	**5.86**	**16.15**	**2.30**	**21.86**	**18.45**	**88**	**0.40**	**1.90**	**0.14**	**0.14**	**17.53**
EZ 4																						
A	0-15	5.40	4.40	0.22	2.20	3.80	1.23	10.00	0.42	0.02	8.24	4.94	13.62	1.72	24.23	15.34	89	0.56	1.16	7.56	0.13	25.23
Bwg	15-30	5.50	4.40	0.11	1.56	2.70	0.94	14.18	0.28	0.03	8.48	4.76	13.55	2.19	23.10	15.74	86	0.95	1.24	7.88	0.19	29.45
Bg1	30-65	5.60	4.40	0.10	1.10	1.90	0.81	11.00	0.25	0.02	9.65	7.04	16.96	1.59	23.02	18.55	91	0.55	1.04	5.66	0.11	20.34
2Bg1	65-80	5.50	4.40	0.07	1.38	0.66	0.30	5.43	0.23	0.03	8.28	7.43	15.97	1.87	21.44	17.84	90	0.45	1.42	7.96	0.17	38.30
2Bg2	80-100	5.90	4.50	0.05	0.13	0.22	0.21	2.60	0.24	0.03	10.87	8.02	19.16	1.65	22.17	20.81	92	0.60	1.05	5.05	0.14	32.43
	Mean	**5.58**	**4.42**	**0.11**	**1.07**	**1.86**	**0.70**	**8.64**	**0.28**	**0.03**	**9.10**	**6.44**	**15.85**	**1.80**	**22.79**	**17.66**	**90**	**0.62**	**1.18**	**6.81**	**0.15**	**30.10**
IO4																						
A	0-20	5.90	4.30	0.24	2.34	4.05	1.33	9.75	0.37	0.04	7.24	3.92	11.57	1.34	23.72	12.91	90	0.11	1.23	9.53	0.31	16.24
Bwg1	20-35	6.10	5.30	0.13	1.74	3.00	0.12	13.38	0.29	0.04	7.84	4.32	12.49	1.42	23.71	13.91	90	0.27	1.15	8.27	0.29	20.11
Bwg2	35-52	6.40	5.30	0.09	1.10	1.90	0.78	12.22	0.20	0.02	9.28	6.08	15.58	1.57	20.91	17.09	91	0.38	0.98	5.73	0.12	18.30
Bg1	52-70	5.60	4.30	0.06	0.32	0.56	0.69	5.33	0.22	0.02	10.28	8.80	19.32	1.29	22.03	20.61	94	0.23	1.06	6.03	0.10	15.52
2Bg1	70-100	5.70	4.30	0.06	0.12	0.21	0.88	2.00	0.23	0.03	6.40	8.52	15.18	1.38	22.89	16.56	92	0.10	1.28	7.57	0.18	23.44
	Mean	**5.94**	**4.70**	**0.12**	**1.12**	**1.94**	**0.76**	**8.54**	**0.26**	**0.03**	**8.21**	**6.33**	**14.83**	**1.39**	**22.65**	**16.22**	**91**	**0.25**	**1.14**	**7.43**	**0.20**	**18.12**
TB4																						
A	0-8	5.48	4.67	0.20	2.28	3.94	0.52	11.40	0.12	0.02	5.83	4.40	10.37	1.60	14.60	11.97	87	0.12	1.48	12.36	0.17	31.60
Bwg1	8-20	5.61	4.90	0.15	1.80	3.11	0.49	12.00	0.12	0.03	4.00	2.67	6.82	1.56	13.40	8.38	81	0.20	1.36	16.23	0.36	25.30
Bg	20-35	5.54	4.91	0.11	1.42	2.46	0.70	12.91	0.08	0.02	6.70	2.33	9.13	2.76	13.99	11.89	77	0.84	1.92	16.15	0.17	14.40
2Bg1	35-60	5.74	4.94	0.08	1.06	1.83	0.94	13.25	0.09	0.02	6.10	4.67	10.85	2.40	16.18	13.28	82	0.60	1.80	13.55	0.15	21.80

2Bg2	60-100	5.58	4.86	0.05	0.87	1.50	0.82	17.40	0.09	0.02	8.65	4.05	12.81	2.10	15.92	14.91	86	0.21	1.89	12.68	0.13	18.35
	Mean	**5.59**	**4.86**	**0.12**	**1.49**	**2.57**	**0.69**	**13.39**	**0.10**	**0.02**	**6.26**	**3.12**	**10.00**	**2.08**	**14.82**	**12.09**	**83**	**0.39**	**1.69**	**14.19**	**0.19**	**22.29**

Table 4: Taxonomic Classification of Pedons in the Study Area Soils of the Backswamp Physiographic or Mapping Unit

		USDA					
Pedon	**Drainage**	**Order**	**Suborder**	**Great group**	**Sub group**	**Family**	**WRB**
OG4	VPD	Inceptisol	Aquepts	Endoaquepts	Typic Endoaquepts	Very fine, mixed, aquic, isohyperthermic	Eutirc Gleysol
AE4	VPD	Inceptisol	Aquepts	Endoaquepts	Typic Endoaquepts	Very fine, mixed, aquic, isohyperthermic	Eutirc Gleysol
EZ4	VPD	Inceptisol	Aquepts	Endoaquepts	Typic Endoaquepts	Very fine, mixed, aquic, isohyperthermic	Eutirc Gleysol
IO4	VPD	Inceptisol	Aquepts	Endoaquepts	Typic Endoaquepts	Very fine, mixed, aquic, isohyperthermic	Eutirc Gleysol
TB4	VPD	Inceptisol	Aquepts	Endoaquepts	Typic Endoaquepts	Very fine, mixed, aquic, isohyperthermic	Eutirc Gleysol

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