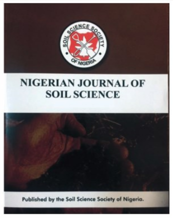
Nigerian Journal of Soil Science

Journal homepage:www.soilsjournalnigeria.com



Characterization and classification of rice-growing soils on Igbaku sandstones residua and current suitability for rice production in Anambra State, Eastern Nigeria

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ARTICLE INFO

Article history:
Received August 20, 2020
Received in revised form September 7, 2020
Accepted November 11, 2020
Available online March 19, 2021

Keywords:
Sandstone residua
Soil characteristics
Haplaquults
Gleyic Cambisols
Suitability for rice

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https://doi.org/10.36265 njss.2021.310109
ISSN– Online **2736-1411**
Print **2736-142X**

ABSTRACT

The soils on Igbaku sandstones residua were sample at Ifite Ogwari in Anambra state Nigeria to characterize, classify and evaluate their current suitability for rice production. Following several auger borings, a modal profile was sited dug, described and sampled. Data from it and representative auger points are presented. The soils generally belong to loamy textural classes or finer, especially in the subsoil layers. The implications of particle size distribution and textural classes obtained suggest high water retentivity favoured by slow permeability, both of which support good rice performance. Again the values of bulk density, pore size distribution and hydraulic conductivity are all in the ranges that favour rice cultivation. Though the soils contained high levels of exchangeable bases, exchangeable acidity was equally high, leading to low base saturation. The soils were classified as Haplaquaults (Soil Taxonomy) and correlated to Gleyic Cambisols (WRBSR). Due to fertility inadequacies, the current suitability of the soils for rice production is the S2f subclass. This implies that for sustainable rice production (especially if three cycles per year is to be achieved) supplementary nutrient especially P_2O_5 from triple superphosphate need to be applied and acid-forming fertilizers should be avoided rather than superphosphates should be used. Based on the soil chemical results, the following recommendations were made: 100-120 kg ha^{-1} Urea, 60 kg P_2O_5 kg ha^{-1} from triple superphosphate and 15 kg ha^{-1} K_2O (muriate of potash).

1.0 Introduction

A review of the future of soil science (Blum, 2006) showed that in countries with food deficiencies especially in Africa, Asia, South, and Central America, soil science would mainly target soil fertility in its broadest sense as long as these deficits existed while in countries with sufficient food supply, soil science would increasingly target environmental and cultural issues, such as protection of the food chain against contamination, protection of groundwater resources, protection of the air and human health as well as protection of soil as a cultural and natural heritage. The latter scenario was based on the fact that clean food, clean water, and clean air were the basis of a healthy environment, guaranteeing a long life expectancy of people. Characterization and classification of soils in countries like Nigeria with insufficient food supplies should be accompanied by land suitability evaluation for making the research more relevant to local users of soil information especially farmers while satisfying the interest of soil researchers. However, earlier characterization and classification of landscape soils in Nigeria (Akamigbo and Asadu, 1983; Akamigbo and Asadu, 1986; Asadu, 1990), as well as detailed information on the relationships between soil properties (Asadu and Akamigbo, 1990; Asadu et al., 1997), remain valid in evaluating such soils for their use in agricultural production. Generally, land use types differ from one location to another depending on the immediate needs of government, community or individual concerned but in Nigeria land is used for agriculture, urban development, industrial and commercial purposes in that order of decreasing importance (FDALR, 1982).

Soil is a dynamic natural body comprising the uppermost layer of the earth, exhibiting distinct organization of their mineral and organic components; including water and air, which formed in response to atmospheric and biospheric forces acting on various parent materials under diverse geomorphic conditions over a while, therefore their characterization and classification are necessary to predict their use-values (Yaalon and Arnold. 2000).To assess the suitability of soils for crop production accurately, soil characteristics and crop requirements must be known and understood within the context of limitations imposed by landform and other features which do not form a part of the soil but may have a significant influence on use that can be made of the soil (FAO, 1995). Thus, soil suitability evaluation needs a specification of the respective crop requirements and calibrating them with the terrain and soil parameters (Dent and Young, 1981). In most cases, agricultural lands in Nigeria have been utilized intensively for specific purposes at the expense of their suitability capabilities thereby resulting in land degradation and altering of the natural ecological conservatory balances in the landscape (Senjobi, 2007).

The land evaluation provides a clue to sustainable land use since the land will be used according to its capability. For any given crop species and variety, the yield in terms of harvestable produce (agricultural yield) is affected by soil depth and structure, soil moisture capacity, soil air, soil slope and stoniness, soil reaction, atmospheric and soil temperature, intensity and duration of sunshine, atmospheric humidity, plant pests and diseases, hazards of floods and violent winds as well as acceptable cultural practices (Asadu, 1995). It is the complex interactions between the crops and those several factors and conditions in their environment that determine the performance of any crop. It has been established that Nigeria has all it takes to feed its citizens and place petroleum (oil) behind agriculture as a foreign exchange earner if land resources including soils are properly utilized (Asadu et al., 2012; Asadu, 2017).

The dynamic nature of swampy soils used for rice production continuously demands that such soils be characterized and evaluated regularly to ensure sustainability. This applies more when the sources of water are from streams or rivers passing through several kilometres before their point of use for swamp rice production. Rice is one of the major staple crops grown in Nigeria especially in swamps as a sole crop but sometimes between raised mounds and ridges used to produce such crops as yam, cassava, and maize (Asadu et al., 2019). The importance of rice is increasing in Nigeria as it has become part of the everyday diet of an average Nigerian household and local production needs to be encouraged through appropriate land use recommendations. The wide range of rice-growing conditions suggests an equally wide variety of soils on which rice is grown and the most important suborders soil taxa identified globally in rice-growing areas are Aquents, Aquepts, Ochrepts, Tropepts, Aqualfs, and Aquults. However, locally other suborders such as Uderts are significant (Moormann, 1978). Generally, clayey textures are significantly better than sandy textures in rice production due to their water and nutrient retention capabilities (Dou et al., 2016). Paddy soils are usually medium- to fine-textured; clay to clay loams, silt loams, and silty clay loams because prevention of excessive percolation is a necessity for efficient rice production (Moormann, 1978).

This study characterized the soils that have been used for continuous swamp rice production for over five years, classified them and assessed their current suitability for rice production.

2.0. Materials and methods

2.1 Brief Description of the Location of Study

Ifite Ogwari - Lat. 6° 37.896" N, Long. 6° 56.502" E, is in Ayamelum Local Government Area (LGA) of Anambra state, eastern Nigeria. Detailed descriptions of the geology and geomorphology of areas under study are in Ofomata et al. (1965). Still, the residua of Igbaku sandstones which overlie the Imo clay shales are the parent materials of the soils of Ifite-Ogwari with very gently undulating to nearly level topography (Akamigbo, 1991).

The location belongs to the Kopen classification, an "Awi" climate which is a rainy tropical climate with distinct dry and wet seasons. The average annual rainfall amounts to approximately 1730mm in about 110 rain days, and in recent years, the rainy days seem to be increasing in number (Akamigbo, 1991). The wet season starts from mid-March and lasts till November in normal years. The rainfall pattern is bimodal with peaks June/July and September with a minor dry season often referred to as *August Break* (Asadu 2000). The absolute mean minimum and maximum temperatures are 12°C and 38°C respectively both occurring during the dry season with diurnal variations seldom exceeding 11°C. The relative humidity is high (>75%) in the rainy season. Still, it drops (< 45%) during the dry season, especially during the *harmattan,* a north-easterly dry wind that blows intermittently between December and March (Akamigbo,1991).

The general vegetation belongs to the Derived Savannah zone which owes its origin to biotic disturbance resulting from clearing the original forest for cultivation and subsequent control by fire. Many of the trees existing now are fire-resistant species but small patches of forest are observed in some places with *Daniella*sp, *Lophira*sp, *Nauclea* sp, Borassus palms, and some fruit trees such as mangoes, citrus, and oil palms as dominant tree species. Crop farming is the prevailing current land use, a thriving venture in the entire area. Rice cultivation dominates over other crops such as maize, sugar cane, yams, cassava and pigeon pea, especially in the floodplains (Asadu et al., 2019).

2.2 Method of Survey Adopted

The field survey was carried out from July 22 to 29, 2017. The topographic maps guided the location of the sampling points, and their precise locations were captured with the help of the Global Positioning System (GPS) equipment etrex-Legend. After the preliminary soil examination by free survey technique using auger samples, soil samples were collected from both selected auger points and two modal profile pits (only one presented). However, the shallow depth to the water table did not allow digging beyond 56 cm, but a screw auger was used to collect soil samples up to 120 cm depth. The profile pits were studied and sampled according to the procedure set out in USDA and FAO/UNESCO guidelines for soil profile study and summarized in Schoeneberger, et al., eds (2002). Instructions contained in FMARD (2017) report was adhered to during the field sampling. Soil samples were collected from identifies pedogenic horizons after macro-morphological characterization. Again undisturbed core samples were also collected from 0-20 cm and 20-40 cm depths using metallic core samplers for hydraulic conductivity, pore size distribution and bulk density determinations near the profile pit and auger point locations. The soil properties from the auger points and topsoils of the modal profiles were summarized and used for the current suitability evaluation of the soils for rice cultivation. In contrast, those from the modal profile pits were used for the characterization and classification of the soils.

2.3 *Laboratory Determinations and Theoretical Crop Requirements*

All the analyses were carried out at the Department of Soil Science Laboratory, the University of Nigeria, Nsukka following standard laboratory procedures: Soil bulk density was determined by the undisturbed core sampling method (Blake, 1965) after drying the soil samples in an oven at 105°C. Pore size distribution was determined using the water retention data as follows: Macroporosity from the volume of water drained at 60cm of tension/ volume of bulk soil; microporosity from the volume of water retained at 60cm of tension/volume of bulk soil; and total porosity from the sum of macroporosity and microporosity (Brady and Weil, 2002). After air-drying the loose samples and gentle crushing, they were sieved with a 2mm sieve. Soil particle size distribution was determined by the Bouyoucos hydrometric method (Van Reeuwijk, 1992) using sodium hydroxides (NaOH) as a dispersing agent. Soil pH was measured in water and potassium chloride (1N KCl) suspension in a 1:2.5 (soil: liquid ratio) potentiometrically using a Beckman's zeromatic glass electrode pH Meter. Available P was extracted with Bray (II) solution (Bray and Kurtz; 1945) and measured using a colourimeter. Soil organic carbon content was determined using Walkley-Black's titration method (Jackson, 1973). Total N was determined using the Kjeldahl digestion, distillation, and titration method as described by Bremner (1965) by oxidizing the organic matter in concentrated sulphuric acid (0.1N H_2SO_4). Cation Exchange Capacity (CEC) and Exchangeable bases (Ca, Mg, K and Na) were determined after extracting the soil samples by ammonium acetate (1N NH_4OAc) at pH 7.0. Exchangeable Na and K in the extracts were determined by Flame photometry (Rhoades, 1982) while Exchangeable Ca and Mg in the extracts were determined by the titration method using 0.1N EDTA (Chapman, 1965). Cation Exchange Capacity (CEC) was estimated titrimetrically using 0.1N NaOH (Chapman, 1965). Exchangeable Acidity (EA) was determined by saturating samples with potassium chloride solution (1N KCl) and titrated with sodium hydroxide as described by Mclean (1965). Percentage Base Saturation was determined by calculation as follows:

$$\%BS = TEB/ECEC \times 100$$

Where; %BS = percentage base saturation; TEB = total exchangeable bases and ECEC = effective cation exchange capacity.

Exchangeable sodium percentage (ESP) was calculated from exc. Na x100/CEC.

The variability in soil properties was evaluated using the coefficient of variation (standard deviation/mean x 100)

2.4 Soil Classification and Suitability Evaluation

The soil classification systems used was the Soil Taxonomy (USDA, 2014) correlated to the World Reference Base for soil resources (FAO/UNESCO, 2014). The land and soil requirements for rice production (Dent and Ridgway, 1986) adopted are shown in Table 1. The FAO (1976) Suitability classification was used to evaluate the land for suitability in rice cultivation to place them into any of the five suitability classes ranging from "Unsuitable" to "Highly Suitable" using the principle of limiting condition by matching the soil characteristics with the requirements of the crops (FAO, 1995).

Table 1: Land and Soil Requirement for Rice

Land qualities	Land characteristics	Limiting values for land characteristics			
		S1	S2	S3	N
Sufficiency of energy	Mean annual temperature, (°C) or	>24	21-24	18-21	<18
	Elevation (m)*	0-600	600-1200	1200-1800	>1800
Sufficiency of water	75% probability rainfall (mm)	>1300	900-1300	500-900	<500
	Soil drainage class	Poorly drained	Imperfectly drained	Moderately well-drained	Excessively drained
	Soil texture	C, SiC, SiCL, L	SC, SCL, SiL, Si	SL	S, LS
	Soil depth (cm)	>80	60-80	40-60	<40
Sufficiency of nutrients	pH of flooded soil	6-7	5- 6	4.5-5	<4.5
			7-8	8-8.5	>8.5
Salinity hazard	EC_e(mS cm^{-1})	<3	3-5	5-7	>7
Ease of water control	Slope angle (degrees)	<1	1 -2	2-6	>6
Ease of cultivation	Stones and rock outcrops (%)	Nil	1-5	5-10	>10

Source: Dent and Ridgway (1986)

Table 2: Suitability Classes and their Description

Suitability Class	Description
Class S1: Highly Suitable	Land having no significant limitations to the sustained application of a given use, or only minor limitations that will not significantly reduce productivity or benefits and will not raise inputs above an acceptable level.
Class S2: Moderately Suitable	Land having limitations which in the aggregate are moderately severe for sustained application of a given use; the limitations will reduce productivity or benefits and increase required inputs to the extent that the overall advantage to be gained from the use, although still attractive, will be appreciably inferior to that expected on Class S1 land.
Class S3: Marginally Suitable	Land having limitations which in the aggregate are severe for sustained application of a given use and will so reduce productivity or benefits, or increase required inputs, that this expenditure will be only marginally justified.
Class N1 Currently Not Suitable	Land having limitations that may be surmountable in time but which cannot be corrected with existing knowledge at a currently acceptable cost; the limitations are so severe as to preclude successful sustained use of the land in the given manner.
Class N2: Permanently Not Suitable	Land having limitations that appear as severe as to preclude any possibilities of successful sustained use of the land in the given manner.

Source:(FAO, 1976)

3.0. Results and Discussion

3.1 Soil Physical Properties

3.1.1 Particle size distribution and texture

Based on the FAO (1987) textural grouping the soils are dominated by medium to fine textures (Table 3). However, most belong to a loamy textural class or finer textures, especially in the subsoil layers. None of the textures would offer restricted root growth to arable crops, including rice (FAO, 1988). The general increase in clay fraction with depth indicates the accumulation of this fraction in the subsoil or B-horizon. This can be used to predict the eluviation/illuviation process of lessivage in the soils. Even though total sand fractions dominated over clay and silt fractions, fine sand dominated over coarse sand. The three fractions clay, silt and fine sand which dominated over coarse sand favour soil water storage capacity. The implication of particle size distribution and textural classes obtained in these soils is that high water retention is favoured and permeability is not rapid. These conditions favour water availability for rice production in soils, whether from rainfall or irrigation.

Table 3: Particle size distribution and soil textures of modal profile and auger samples

Profile No. /Horizon	**Depth (cm)**	**Clay**	**Silt**	**Fine sand**	**Coarse sand**	**Total sand**	**Textural Classes***
			g kg^{-1}				
Profile 2							
Ap	0-14	340	340	230	90	320	CL
Bt1	14-36	360	300	230	110	340	SCL
Bt2	36-56	440	260	240	60	300	C
BC	56+	400	300	220	80	300	C
AugerP1Topsoil	0-20	280	420	250	50	320	CL
Subsoil layer 1	20-40	320	320	190	170	360	CL
Subsoil layer 2	40-60	360	300	190	150	340	CL
AugerP2Topsoil	0-20	260	300	300	140	440	CL
Subsoil layer 1	20-40	260	280	480	80	560	SCL
Subsoil layer 2	40-60	400	300	220	80	300	C
Auger P3Topsoil	0-20	180	280	360	180	540	SL
Subsoil layer 1	20-40	300	400	200	100	300	CL
Subsoil layer 2	40-60	400	300	220	80	300	C
Mean		330.7	315.38	256.15	105.38	363.08	
Coefficient of variation (CV, %)		22.2	14.7	31.7	39.6	25.2	

Note : C= clay, L= loam, S= sandy,

3.1.2 Bulk density, pore size distribution and hydraulic conductivity

The mean values of some structural and hydraulic properties of the top and subsoils are shown (Table 4). The range of values for soil bulk density is 1.16 to 1. 54 g cm^{-3} with the mean in both layers < 1.40 g cm^{-3}. Thus the bulk density values obtained are not root-restrictive because soil bulk density is considered root-restrictive if it is above the threshold value of 1.60 g cm^{-3} (Vespraskas, 1987). However, the soil should be well puddled before planting. This is because soils with appreciable clay content, once puddled, initially show a decrease in bulk density, which slowly increases over the season.

The data on porosity parameters (total porosity, macro-and microporosity) of the soil show that generally, the topsoils are more porous than the subsoils. However, the differences are not very substantial. On average, the soils have less than 50% of their volume occupied by pores; therefore, their porosities can be said to be slightly less than the hypothetical 50% expected of general agricultural soils but favours rice cultivation

The pore size distribution is disproportionately in favour of microporosity, understandably due to the high to reasonably high clay content of the soils. The disproportionately high microporosity implies greater water retention and availability in the soils which favour rice cultivation.

The saturated hydraulic conductivity (Ks) was consistently lower in the subsoils than the topsoils. But in class moderately slow generally. By this rating, all the soils come under the permeability classes' moderate' to 'very slow'. This implies that the rate of transmission of water through the soil, as defined by their texture and structure, is intermediate and low in the soils. With the topsoils being permeable, rainwater and irrigation water would be readily intercepted into the soil; the intermediately permeable subsoils would not allow all such water to be lost to excessive drainage. Again, this is a good attribute of the soil in terms of water retentivity for rice cultivation.

Table 4: Bulk density, pore size distribution and hydraulic conductivity at positions near the modal profile and where the auger samples were taken

Position	**Depth (cm)**	**Bulk density**	**Total porosity**	**Macro-porosity**	**Micro-porosity**	**K$_s$**
		(g cm-^{3})		(%)		(cm h^{-1})
Modal profile	0-20	1.16	48.45	4.88	43.57	0.47
	20-40	1.25	41.59	9.97	31.62	0.56
Position 1	0-20	1.33	45.65	3.08	42.56	0.47
	20-40	1.38	51.22	8.90	42.32	0.56
Position 2	0-20	1.54	50.53	5.06	45.47	0.19
	20-40	1.32	45.41	5.30	40.11	0.22
Mean	0-20	1.34	48.21	4.34	43.87	0.38
	20-40	1.32	46.07	8.06	38.02	0.45

3.2 Soil Chemical Properties

3.2.1 Soil pH, soil organic matter (SOM), total nitrogen (TN)

The soil pH values obtained (Table 5) indicate that all the values were above 5.0 (slightly acid), and suitable for most arable crops, including rice (Dent and Ridgway, 1986). The variation was < 2% across the locations sampled. The SOM values varied from moderately high (21.95g kg $^{-1}$) to very high values (44.65g kg $^{-1}$) with a mean of 33.88 g kg $^{-1}$ while TN content almost followed the same trend as SOM ranging from medium (0.84 g kg $^{-1}$) to high values (1.82 g kg $^{-1}$) with a mean of 1.4 g kg $^{-1}$ (Table 5). The moderate variability in SOM and TN contents in the soils may be due to fluctuating soil water conditions over the years, which influence the rate of SOM decomposition as a result of variations in soil air composition.

Table 5: Soil chemical properties (pH, SOM and total N) of the modal soil profile and selected auger points

Profile No. /Horizon	**Depth**	**pH**		**SOM**	**Total N**
	(cm)	H_2O	KCl	___ g kg^{-1} ____	
Modal Profile					
Ap	0-14	5.3	4.0	34.06	1.68
Bt1	14-36	5.1	4.0	42.38	1.68
Bt2	36-56	5.3	4.0	34.06	1.68
BC	56+	5.2	4.0	21.95	0.84
Auger Samples					
Position1 Topsoil	0-20	5.3	4.0	34.06	1.68
Subsoil layer 1	20-40	5.2	4.0	21.95	0.84
Subsoil layer 2	40-60	5.2	4.0	42.38	1.12
Position2 Topsoil	0-20	5.3	4.2	44.65	1.82
Subsoil layer 1	20-40	5.3	4.0	34.06	1.68
Subsoil layer 2	40-60	5.2	4.0	21.95	0.84
Position3 Topsoil	0-20	5.2	4.0	21.95	0.84
Subsoil layer 1	20-40	5.3	4.2	44.65	1.82
Subsoil layer 2	40-60	5.1	4.0	42.38	1.68
Mean		5.23	4.03	33.88	1.40
Coefficient of variation (%)		1.4	1.9	27.2	30.3

3.2.2 Exchangeable bases, acidity, CEC, Base saturation ESP and available P at Ifite Ogwari

The exchangeable bases were generally high to very high, likewise the total exchangeable bases (Table 6). Exchangeable Ca ranged from 1.0 to 5.4 cmol kg^{-1} averaging over 3.0 cmol kg^{-1} for the entire soil exhibiting a wide variation across the area (CV>50%). Exchangeable Mg was also very high, with a similar range but a lower mean of ≈ 2.2 cmol kg $^{-1}$ and a lower CV of ≈ 40%. Exchangeable K was again very high, ranging from 0.04 to 018 cmol kg^{-1} with a mean of ≈ 0.12 cmol kg^{-1} with a low CV of < 25%. Both exchangeable Na (mean < 0. 06 cmol kg^{-1}) and exchangeable sodium percentage (ESP, mean < 0. 05%) were very low implying that sodicity problems (unstable structure, poor root development etc.) are not likely to occur in the soils. Their respective variations were also low (CV < 30%). The CEC was also very high, ranging from 11.0 to 21.3 cmol kg^{-1} with a mean of ≈ 14.0 cmol kg^{-1} but was dominated by exchangeable acidity. These CEC values suggest that the soils are likely to be of mixed mineralogy composed of illite, halloysite and kaolinite. The variation in CEC was also low (CV < 30%). Exchangeable Al was very high, ranging from 3.2 to 7.6 cmol kg^{-1} with a mean of ≈ 5.5 cmol kg^{-1}. The mean exchangeable H was much lower (mean ≈ 3.6 cmol kg^{-1}) than that of Al. The total exchangeable acidity reflects the strongly acid conditions of the soil as shown by the pH values (Table 5). This is also reflected by a low base saturation of < 40% on average. The available P was very low, with a mean of < 8 mg kg^{-1}. The general fertility status of the soils shows that physical fertility is very suitable for rice production, but chemical fertility is moderately suitable. This implies that for sustainable rice production (especially if three cycles per year is targeted) supplementary nutrient elements especially P need to be applied and acid-forming fertilizer,e.g. ammonium nitrate and sulphate of ammonia should be avoided rather superphosphates should be used. Based on the soil chemical results the following recommendations are made: 100-120 kg ha-1 Urea (5 bags per ha), 60 kg P_2O_5 kg ha-1 (2 ½ bags triple superphosphate per ha) and 15 kg ha^{-1} K_2O (½ bag muriate of potash per ha).

Table 6: Soil chemical properties of the modal soil profile and selected auger points

Profile/Auger	**Depth**	**Ex. Na**	**Ex. K**	**Ex. Ca**	**Ex.Mg**	**TEB**	**CEC**	**Ex. Al**	**Ex. H**	**BS**	**ESP**	**Av.P**
	{cm)			(cmol kg^{-1})						____(%)____		(mg kg^{-1})
Ap	0-14	0.05	0.08	2.4	2.4	4.93	10.72	5.8	4.4	46.0	0.47	1.87
Bt1	14-36	0.08	0.130	1.8	2.4	4.41	11.98	6.6	5.2	36.8	0.67	4.66
Bt2	36-56	0.05	0.08	2.2	3.6	5.93	10.82	7.6	5.2	54.8	0.46	2.80
BC	56+	0.03	0.07	1.0	3.0	4.10	11.52	5.4	4.8	35.6	0.26	2.80
Auger Samples												
Position1 Topsoil	0-20	0.05	0.08	2.4	2.4	4.93	10.72	5.8	4.4	46.0	0.47	1.87
Subsoil layer 1	20-40	0.08	0.130	1.8	2.4	4.41	11.98	6.6	5.2	36.8	0.67	4.66
Subsoil layer 2	40-60	0.08	0.136	5.4	1.0	6.62	19.69	3.2	0.8	33.6	0.41	17.72
Position2 Topsoil	0-20	0.08	0.136	5.4	1.0	6.61	19.69	3.2	0.8	33.6	0.41	17.72
Subsoil layer 1	20-40	0.08	0.130	1.8	2.4	4.41	11.98	6.6	5.2	36.8	0.67	4.66
Subsoil layer 2	40-60	0.08	0.136	5.4	1.0	6.62	19.69	3.2	0.8	33.6	0.41	17.72
Position3 Topsoil	0-20	0.08	0.130	1.8	2.4	4.41	11.98	6.6	5.2	36.8	0.67	4.66
Subsoil layer 1	20-40	0.08	0.136	5.4	1.0	6.61	19.69	3.2	0.8	33.6	0.41	17.72
Subsoil layer 2	40-60	0.08	0.136	2.6	3.2	6.02	10.98	6.6	4.4	54.8	0.73	13.06
Mean		0.069	0.116	3.03	2.169	5.31	13.956	5.42	3.63	39.91	0.516	8.609
(CV, %)		25.3	23.2	55.6	41.2	19.1	28.6	30.1	54.8	19.6	28.5	80.1

Brief Description of Modal Soil Profiles

A. General Information

Profile No. 1

Describer: Charles L.A. Asadu

Date of Description: August 26, 2017
Village: IfiteOgwari, Ayamelum LGA, Anambra state
Location: Lat. 6^{o} 37.896 N, Long. 6^{o} 56.502'E
Parent materials: Weathered Igbaku sandstone and Imo clay shale with fluvial materials
Landform/Topography/ Relief: Gentle slope to almost flat land (2-5% slope)
Elevation: 60.0 m asl
The direction of Slope: East to West direction
Drainage: very poor
Runoff: slow
Permeability: Slow
Internal drainage: very slow
Soil drainage class: Very poor
Stoniness: 0%
Rockiness: 0%
Erosion: very slight inter rill
Higher Categorical Classification: Haplaquults (USDA, Soil Taxonomy) correlated to GleyicCambisols (WRBSR)
General Land Use: Rice production in ponded areas while yam, maize, cassava, *Cajanus cajan* are cultivated in raised mounds in surrounding areas

B. Horizon Description

Designation	**Depth (cm)**	**Description (all colours are moist colours)**
Ap	0-16	Very dark reddish-brown (5YR2/2); Clay Loam; moderate, fine, granular; firm, hard, slightly sticky, plastic; deep penetrable; reddish-brown (5YR4/8), faint, few, fine mottles; many, very fine grassroots; common, very fine pores; clear smooth boundary.
Bt1	16-39	Dull brown (7.5YR5/3); Sandy Clay Loam; strong, medium, granular; firm, very hard, sticky, plastic; deep penetrable; brownish grey(7.5YR5/4), distinct, common, medium mottles; few, very fine grassroots; common, very fine pores; clear smooth boundary
Bt2	39-56	Dull brown (7.5YR5/3); Clay; very firm, very hard, sticky, plastic; deep penetrable; brownish grey(7.5YR5/4), distinct, common, medium mottles; diffuse irregular boundary
BC	56+	Greyish brown (7.5YR5/2); Clay; very firm, very hard, sticky, plastic; deep penetrable; bright brown (7.5YR5/6), prominent, common, medium mottles; diffuse irregular boundary

C. Interpreted Characteristics of the soil/ Remarks

Soil can hold water for a very long time (> 30 days) because of very poor drainage; therefore, it is suitable for swamp rice. Rice can be grown year-round with planned irrigation water from the Omambala river.

3.3 Land Suitability Recommendations

By matching the soil properties and land characteristics outlined by Dent and Ridgway (1986) and respective values obtained eight of the nine criteria placed the soil in the S1 class while the ninth criteria (soil pH) placed the soil under S2 class. Other physical characteristics not mentioned by Dent and Ridgway (1986) such as bulk density, pore size distribution and saturated hydraulic conductivity placed the soils under the S1 class also. Following various nutrient interpretations summarised in Asadu and Nweke (1999)the mean values of SOM, TN, as well as exchangeable basses, are high indicating S1 class. Still, the exchange sites are dominated by exchangeable acidity resulting in low base saturation values, thus placing the soils currently in the S2 class and S2f subclass due to soil fertility inadequacies.

4.0. Conclusion

From the summary of the morphological, physical and chemical properties, the soils were classified as Haplaquults (USDA, Soil Taxonomy) and correlated to GleyicCambisols (WRBFSR). Generally, physical fertility was highly suitable for rice production, but chemical fertility was moderately suitable. The mean values of SOM, TN as well as exchangeable basses were high, placing the soils in suitability class S1. Still, the exchange sites were dominated by exchangeable acidity resulting in low base saturation values, thus setting the soils ina moderately suitable class. The current suitability of the soils, therefore, is S2 class and S2f subclass due to soil fertility inadequacies. This implies that for sustainable rice production (especially if three cycles per year is targeted); supplementary nutrient elements especially P need to be applied, but acid-forming fertilizer,e.g. sulphate of ammonia should be avoided rather than triple superphosphates should be used.

5.0. Recommendation

The general fertility status of the soils indicated that physical fertility was highly suitable for rice production, but chemical fertility was moderately suitable. Thus for sustainable rice production application of nutrient elements, especially P_2O_5 from triple superphosphate is recommended while acid-forming fertilizer,e.g. ammonium nitrate and sulphate of ammonia should be avoided. Based on the soil chemical results, the following recommendations were made: 100-120 kg ha^{-1} Urea (5 bags of 50 kg per ha), 60 kg P_2O_5 kg ha^{-1} (2 ½ bags triple superphosphate per ha) and 15 kg ha^{-1} K_2O (½ bag muriate of potash per ha).

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