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PROFILE CHARACTERISTICS OF SELECTED RICE-PRODUCING SOILS OF ABIA STATE IN SOUTH-EASTERN NIGERIA.

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ABSTRACT

Due to the increasing soil degradation of South-eastern Nigeria – with particular reference to the rice growing soils of the region, selected rice producing soils of Abia State were characterized with a view towards acquiring a holistic understanding of the soils and their fertility status. Random soil survey technique was used in field sampling. Four profile pits were dug in two different towns in Abia State. Soil samples were collected from the profiles according to their genetic horizons for laboratory analyses and their interpretations. The results showed that Clay dominated the particle fractions of the soil. Clay content of the soil ranged from 578.00 – 730.80 gkg^{-1}and did not follow uniform trend in its distribution down the profile pit.The soil had low sand (89 – 232 gkg^{-1}) and moderate silt contents. Bulk density values increased down the profile in all the pedons and were below the minimum bulk value at which root-restricting conditions will occur. The pH ranged from very strongly acidic (4.34) to moderately acidic (5.31). The soils had high organic matter (> 20 gkg^{-1}), moderate to high total nitrogen and high base saturation. Available phosphorus was acutely deficient in all the soils (< 4 mgkg^{-1}) .Though low in available phosphorus contents, the soils can still produce increased and sustainable rice yield if the appropriate management practices are adopted, with particular reference to phosphate fertilizer application.

Keywords: Fertility status, Profile Characteristics, Rice-producing soils.

INTRODUCTION

Given the central role of soil resources in subsistence crop production, and the fact that soil, as a non renewable resource on the human time scale, is a major aspect of sustainable agriculture (Pawluk *et al.,* 1992; Ettema 1994), the profile characteristics of soils has recently received more attention. As surface characterization of tropical soils has failed to bring about detailed information on soils, it has become more and more apparent that the detailed information on profile characteristics of soil can offer many insights about sustainably managing soil, with reference to rice producing soils. Natural resources, including soils cannot be properly managed without proper understanding of their characteristics (Idoga *et al.,* 2005). With a goal of self sufficiency, the Federal Republic of Nigeria has initiated several projects such as the National Special Project on Food Security, Presidential Task Force on Cassava and Rice production etc. Management technologies to backstop these projects require knowledge of the soils and specifically their profile attributes.

The rice- producing soils investigated represent the most important agricultural soils of Abia state. Detailed information on rice-producing soils of the study area is scarce, yet the need to generate soil data to improve rice production exists. Such detailed information on soil that should guide agricultural use and management of soil resource is not readily available to farmers; where it exists, it is of limited significance to farmers (Olatunji, 2007). Therefore, the major objective of this study is to study the profile characteristics of selected rice producing soils of Abia State, South-eastern Nigeria.

MATERIALS AND METHODS

Study Area

Uzuakoli in Bende LGA, Abia State of South-eastern Nigeria is located between Latitudes 4^0 71^1N and 6^0 30^1, Longitudes 7^0 54^1 and 8^0 58^1 E. Soils are derived from Shale (Bende Ameki group) . The area receives an average of 2134 mm rainfall distributed to about 139 days of the year. The daily temperature ranges from 21 ^{0}C to 34 ^{0}C. The relative humidity reaches a minimum of 60 % in January (at the peak of the dry season) and rises to 80 - 90 % in July (at the peak of the rains) (National Root Crop Research Institute Umudike meteorological unit 2012). The original vegetation of the study area was the tropical rain forest (Igbozuruike, 1975; FDALR, 1985). The rain forest has however been destroyed largely through human activities and supplanted with what is today referred to as the oil palm bush.

Field Studies

Random soil survey technique was used in field sampling. Four profile pits were sunk in two different paddy soil types namely upland and lowland. The study sites and profile pits were geo-referenced with the aid of a hand held Global Positioning System (GPS) receiver. The profile pits were described using FAO, (2006) guidelines, delineation of horizon boundaries was accomplished before actual sample collection for laboratory analyses and samples were collected according to horizons. The soil samples were air dried, crushed and sieved through a 2 mm sieve mesh. A small quantity (about 10 g) of each sample was finely ground and preserved for determination of organic carbon and total nitrogen. Undisturbed soil samples for determination of bulk density were collected using core samplers.

Laboratory Soil Analyses

Soil colour was determined using Munsell colour chart while other morphological properties were determined with visual observation, hand feeling and measurement. The physical and chemical properties of the soil samples were determined using routine analytical methods. Particle size distribution was carried out by hydrometer method (Gee and Or, 2002). Bulk density was determined using the procedure outlined by Arshad *et al.* (1996). Porosity was computed from bulk and particle density as described by Vomocil (1965). The moisture content was determined gravimetrically. Soil pH was measured electrometrically by glass electrode in pH meter in distilled water suspension using a soil: liquid ratio of 1: 2.5 (Thomas, 1996). Exchangeable bases (Ca, Mg, K, Na) were extracted with neutral ammonium acetate (NH_4OAc). Exchangeable calcium and magnesium were determined by ethylene diamine-tetraacetic acid (EDTA) titration method while exchangeable potassium and sodium were estimated by flame photometry (Jackson, 1962). Exchangeable acidity was extracted with KCl (1 N) and measured titrimetrically according to the procedure of Mclean (1982). Effective Cation Exchange Capacity (ECEC) was the sum of the exchangeable bases and the exchangeable acidity, while base saturation, was computed as the percentage of the ratio of exchangeable bases to ECEC. Aluminum saturation (Al sat), was computed as the percentage of the ratio of exchangeable aluminum to ECEC. Soil Organic carbon (SOC) was determined by Walkley and Black digestion method (Nelson and Sommers, 1982), organic matter was computed by organic carbon x 1.724. Total Nitrogen was estimated by micro-Kjeldahl digestion method (Bremner and Mulvaney, 1982) while available phosphorus was determined by Bray II Method (Olsen and Sommers, 1982).

Statistical Analysis

Data generated were subjected to mean and coefficient of variation analyses. The coefficient of variation was ranked according to the procedure of (Wilding, 1985) where Cv < 15% = low variation, Cv >15 < 35% = moderate variation, Cv > 35 % = high variation.

RESULTS AND DISCUSSION

Morphological properties of soils

The details of the morphological properties of soils are presented in Table1. Soil colour matrix ranged from very dark reddish brown (5YR 2/4) to greyish yellow (10 YR 5/6) across the soils studied. Soil consistence ranged from firm at the surface horizons to very firm down the profile with exception of the surface horizon (Ap) of the upland profile 1. Generally, from the results it was observed that the firmness of the soils increased down the profiles in all the soil types investigated. In addition to this, soils were poorly drained except in soils of the upland. This could be attributed to the clayey nature of these soils. Clayey soils contain small pores which inhibit the easy movement of water down the profile. Good drainage is a result of abundance of macro pores in soils (Barker *et al.*, 2004). The root composition of the soils showed presence of very fine roots at the surface horizons across all the soils studied. No root was seen at the deepest horizons of these soils.

Physical properties of soils

The particle size analysis revealed that all the

Table 1: Morphological properties of soils

Hor.	Soil colour	TC	Drainage	Consistence (moist)	Boundary	Root composition
Upland profile 1						
Ap	5YR 2/4	C	WD	Friable	Csb	Very many fibrous roots
AB	2.5 R 2/3	C	WD	Firm	Csb	Very many fibrous roots
Bt1	2.5 YR 4/2	C	WD	Very firm	Db	Few tap roots
Bt2	2.5 YR 3/6	C	ID	Very firm		No roots
Upland profile 2						
Ap	7.5 YR 3/2	C	WD	Firm	Csb	Very many fibrous roots
AB	2.5 R 2/3	C	WD	Firm	Csb	Very many fibrous roots
Bt1	2.5 YR 4/2	C	ID	Very firm	Gsb	Few tap roots
Bt2	2.5 YR 3/6	C	ID	Very firm		No roots
Lowland profile 1						
Ap	10.5 YR 3/2	C	ID	Firm	Awb	Very many fibrous roots
AB	7.5 R 2/3	C	PD	Firm	Asb	Few fibrous roots
Bt1	2.5 YR 4/2	C	PD	Very firm	Csb	No roots
Bt2	2.5 YR 3/6	C	PD	Very firm		No roots
Lowland profile2						
Ap	10. 5 YR 2/3	C	ID	Firm	Csb	Very many fibrous roots
AB	10.5 R 4/2	C	PD	Firm	Csb	Few fibrous roots
Bt1	10 YR 2/6	C	PD	Very firm	Db	No roots
Bt2	10 YR 5/6	C	PD	Very firm		No roots

C = clay, WD = well drained, ID = imperfectly drained, PD = poorly drained, csb = clear smooth boundary, awb, abrupt wavy boundary, asb = abrupt smooth boundary, gsb = gradual smooth boundary, db = Diffused boundary horizons irrespective of the soil types have clayey texture. Silt contents of the soils decreased with soil depth with exception of profile 1 of the lowland while the distribution of sand and clay did not follow a uniform trend of distribution down the pit. The moderate silt content (181 – 210 gkg^{-1}) observed in this study contradicts the assertion of Akamigbo (1984) that soils of South-eastern Nigeria are low in silt as a result of the high degree and extent of weathering and leaching they have undergone. The soil texture reflects the nature of the parent material from which the soils are developed. Soil texture has an important role in the assessment of soil characteristics. The uptake capacity of soil, which is an indicator of soil fertility, depends on the texture composition of the soil. According to Loide, (2004), as the percentage of clay particles and colloids contained in the soil increase, the content of plant nutrients bound by these particles and colloids increases as well. Thus the soil's nutrient binding capacity dictates how easily the nutrients not bound by soil particles can be washed out of the soil. Variability in clay distribution down the profile pits was low (cv < 15%) with exception of profile pit 2 of lowland with moderate variation (cv > 15 %). Moderate to low variation observed in the vertical distribution of clay showed homogeneity among the horizons and precludes the existence of well

Table 2: Physical Properties of Soil

Horizon	Sand(gkg^{-1})	Silt (gkg^{-1})	Clay(gkg^{-1})	SCR	BD (gcm^{-3})	MC (%)	TP (%)
Upland Profile 1							
Ap	92.0	280.0	628.0	0.45	1.34	5.80	49.40
AB	52.0	160.0	788.0	0.2	1.37	6.63	48.30
Bt1	112.0	146.0	748.0	0.19	1.41	11.03	46.79
Bt2	101.0	140.0	759.0	0.18	1.86	8.60	29.81
Mean	**89.25**	**181.5**	**730.8**	**0.26**	**1.50**	**8.015**	**43.58**
Cv (%)	29.3	36.5	9.7	51.1	16.4	29.0	21.2
Upland Profile 2							
Ap	92.0	240.0	668.0	0.36	1.24	5.96	53.96
AB	232.0	200.0	568.0	0.35	1.24	8.20	53.20
Bt1	142.0	190.0	668.0	0.28	1.41	12.07	46.79
Bt2	152.6	180.0	668.0	1.71	1.62	16.30	38.87
Mean	**154.65**	**202.5**	**643.0**	**0.65**	**1.38**	**10.63**	**48.21**
Cv (%)	37.5	13.0	7.8	98.9	13.1	42.7	14.5
Lowland Profile 1							
Ap	132.0	260.0	608.0	0.43	1.21	5.19	54.33
AB	252.0	200.0	548.0	0.36	1.51	13.00	43.01
Bt1	372.0	120.0	508.0	0.24	1.55	19.99	41.5
Bt2	172.0	180.0	648.0	0.28	1.67	15.59	36.9
Mean	**232.0**	**190.0**	**578.0**	**0.33**	**1.49**	**13.44**	**43.94**
Cv (%)	45.6	30.4	10.8	25.8	13.2	43.2	16.8
Lowland Profile 2							
Ap	152.0	300.0	548.0	0.54	1.15	5.32	56.6
AB	232.0	200.0	568.0	0.35	1.19	12.82	55.09
Bt1	72.0	180.0	748.0	0.24	1.57	17.62	40.75
Bt2	112.0	160.0	728.0	0.22	1.7	16.64	35.84
Mean	**142.0**	**210.0**	**648.0**	**0.34**	**1.403**	**13.10**	**47.07**
Cv (%)	48.1	29.6	16.1	43.4	19.5	42.6	22.0

BD = Bulk density, MC = Moisture content, TP = Total porosity, Cv = Coefficient of variation, Cv $\leq$ 15% = low variation, Cv > 15 $\leq$ 35%= moderate variation, Cv >35% = high variation, developed argillic horizons.. This trend of clay distribution down the profile observed in this study disagrees with the reports by Udoh *et al*., (2008); Chikezie *et al*., (2009) who reported increased clay content with soil depth.

Silt/clay ratios of the soils were generally low (0.26 – 0.65). The low SCR observed in these soils revealed the weathering stage of these soils. According to Mbagwu (1985), the silt-clay ratio of soils reflects the weathering stage of parent material from which the soils are derived. Apart from the use of silt/clay ratio as index of weathering, Morgan (1979) associated high ratios with erodible areas where the continual removal of the soil allows insufficient time for a high degree of weathering to occur.

Bulk density of the soils ranged from 1.38 to 1.50 gcm^{-3} and increased regularly with depth in all the profile pits. Least bulk density values were recorded in the surface horizons with corresponding high organic matter revealing the influence of organic matter on soil compaction. Several authors have reported the significant influence of organic matter on soil bulk density (Akamigbo, 1999; Ahukaemere, 2012). Results of bulk density were less than the critical limits for root restriction (1.75 – 1.85 gcm^{-3}) (Soil Survey Staff, 2003). Lowland paddy soils contained higher quantity of available water compared to those of the upland. This could be as a result of irrigation practices which are regularly done on these soils.

Chemical properties of soils

Soil pH ranged from 4.34 – 5.31 and did not follow a uniform pattern of distribution within the profiles. The total nitrogen contents of the soils ranged from 1.43 -1.58 gkg^{-1} while the organic matter content of the soils ranged between 29.00 and 33.00 gkg^{-1}. Total nitrogen and organic matter contents of the soils decreased down the profiles in all the soils investigated. This could be due to the application of both organic and inorganic fertilizers on the soil surface by farmers. In addition, high nitrogen content of the surface horizons indicates little or no leaching losses in these soils, and could be attributed to the clayey nature of the soils. However, the results of coefficient of variation analysis showed that both total nitrogen and organic matter showed high variation (cv > 35 %) in all the profile pits studied. The available P content of the soil was extremely low (0.98 – 2.18 $mgkg^{-1}$) compared to the critical value of 15 $mgkg^{-1}$ (Enwezor *et al*., 1990) and may be as a result of high P adsorption capacity of the soils. Idigbor *et al* (2008) reported high P fixation in some soils of Abia State. The average P content of the soils showed high variation in all the soils with exception of profile 2 of the upland soils that varied moderately (Table3).

Exchangeable Calcium and magnesium were generally moderate (2.4 -2.9 $cmolkg^{-1}$ 1.3 – 1.9 $cmolkg^{-1}$) as values were higher than the critical values of 2 and 1.2 $cmolkg^{-1}$ and could be attributed to the nature of parent rock and low leaching capacity of these soils.The less leaching capacity of the soils studied irrespective of the soil types was further explained by the low concentration of Ca and Mg in the argillic horizons, revealing the inherent capacity of these soils to retain nutrient elements especially at the crop rooting zone. The exchangeable base cations had medium to high variation and did not follow uniform pattern of distribution down the profiles across the soils investigated. The effective cation exchange capacity of the soils was intermediate and dominated by total exchangeable bases. Moderate to high cation exchange capacity which is a consequence of high clay and

Table 3: Chemical properties of soil

Horizon	pH (H_2O)	OM gkg^{-1}	TN gkg^{-1}	Av. P $mgkg^{-1}$	Ca^{+2}	Mg^{+2}	Na^{+}	K^{+} $cmolkg^{-1}$	Al^{+3}	H^{+}	TEA	TEB	ECEC	BS (%)	Al. sat (%)
Up land profile 1															
Ap	5.20	65.00	3.2	2.63	3.6	1.4	0.27	0.11	0.2	0.1	0.30	5.38	5.68	94.7	3.5
AB	4.84	31.00	1.5	3.86	2.6	1.4	0.21	0.09	1.3	1.6	2.90	4.3	7.20	59.7	18.1
Bt1	4.75	20.00	0.9	1.23	1.8	1.4	0.05	0.04	1.2	0.3	1.50	2.89	4.89	59.1	24.53
Bt2	4.76	19.00	0.7	1.0	1.42	1.0	0.05	0.03	1.15	0.28	2.43	2.50	3.93	63.6	29.26
Mean	**4.89**	**33.0**	**1.58**	**2.18**	**2.355**	**1.3**	**0.15**	**0.07**	**0.96**	**0.57**	1.78	**3.77**	**5.43**	**69.3**	**18.85**
Cv (%)	4.40	65.00	72.10	61.10	41.0	19.2	77.5	57.2	53.2	121.5	38.00	35.10	25.50	24.60	**53.2**
Upland profile 2															
Ap	5.19	63.00	3.1	1.39	4.0	2.8	0.31	0.14	0.3	0.3	0.60	7.25	7.85	92.3	3.82
AB	5.19	32.00	1.6	0.76	2.2	1.2	0.16	0.09	1.1	0.3	1.40	3.65	5.03	73.1	21.86
Bt1	4.5	11.00	0.9	0.89	1.93	0.84	0.13	0.06	1.2	0.9	2.10	2.96	4.25	69.6	28.23
Bt2	4.46	8.20	0.4	0.87	1.8	0.8	0.1	0.06	1.3	1.0	2.30	5.01	5.26	50.4	24.71
Mean	**4.85**	**29.00**	**1.5**	**0.98**	**2.48**	**1.41**	**0.18**	**0.09**	**0.98**	**0.63**	1.60	**4.72**	**5.60**	**71.4**	**19.66**
Cv (%)	12.20	87.90	78.30	28.70	41.3	66.9	53.3	43.1	46.9	60.4	41.11	40.1	27.90	24.10	**55.3**
Lowland profile 1															
Ap	5.4	55.00	2.7	3.81	3.6	2.4	0.23	0.19	0.2	0.2	0.40	6.42	8.82	94.1	2.91
AB	5.33	44.00	2.1	1.09	5.2	3.6	0.37	0.24	0.6	0.1	0.70	9.41	10.11	93	5.93
Bt1	5.24	12.00	0.6	1.31	1.6	1.0	0.66	0.03	0.2	0.5	0.70	2.69	3.39	79.3	5.89
Bt2	5.27	6.80	0.3	0.52	1.2	0.6	0.69	0.06	0.1	0.2	0.30	1.95	2.25	86.6	8.88
Mean	**5.31**	**29.0**	**1.43**	**1.68**	**2.9**	**1.9**	**0.49**	**0.13**	**0.28**	**0.25**	0.53	**5.12**	**6.14**	**88.3**	**5.90**
Cv (%)	1.30	80.3	81.30	86.00	64.1	72.2	46.0	77.7	80.6	69.3	26.20	67.70	63.50	7.70	**41.3**
Lowland profile 2															
Ap	4.66	64.00	3.2	0.86	3.2	1.8	0.24	0.32	1.4	0.4	1.80	5.56	7.36	75.5	19.03
AB	5.3	25.00	1.12	2.63	2.2	1.2	0.09	0.15	0.5	0.2	0.70	3.64	4.34	83.8	11.52
Bt1	5.24	21.00	1.00	2.69	3.6	1.2	0.14	0.21	0.6	0.1	0.70	5.15	5.85	88.00	12.63
Bt2	5.46	10.00	0.50	0.91	2.0	1.2	0.13	0.08	1.0	0.2	0.40	3.41	4.61	74.00	21.69
Mean	**5.17**	**30.0**	**1.46**	**1.77**	**2.75**	**1.35**	**0.15**	**0.19**	**0.88**	**0.23**	0.90	**4.44**	**5.54**	**80.3**	**16.22**
Cv (%)	6.80	78.3	82.1	57.8	28.1	22.2	42.5	53.5	47.0	55.9	37.10	24.20	24.90	8.40	30.4

ECEC = Effective Cation Exchange Capacity, TEA. = Total Exchange Acidity, Ca = Calcium, Mg = Magnesium, K = Potassium, Na = Sodium, w =Water, OM. = Organic Matter, TN = Total Nitrogen, Av. P = Available Phosphorus, Al = Aluminium, Al. sat = Aluminium saturation, H = Hydrogen, Cv = Coefficient of variation, Cv ≤ 15% = low variation, Cv > 15 ≤ 35% = moderate variation, Cv >35% = high variation organic matter content, renders soils suitable for intensive agriculture. Aluminium saturation ranged from 5.90 % to 19.03 %. Sanchez (1976) reported that there is less than 1.0 ppm aluminium in the soil solution when aluminium saturation is less than 60 %, but rises sharply when aluminium saturation increases beyond 60 %. As such, due to the low aluminium saturation (< 20 %) in the soils, there is little risk of aluminium toxicity.

CONCLUSION

Currently, the status of organic matter, total nitrogen and exchangeable bases were moderate in both upland and lowland soils for rice production. Available P deficiency was observed in both soils. However, for optimum rice performance, both soil types require fertilizer application with particular reference to adequate phosphate fertilizer.

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