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Fertility Status and Characterization of Paddy Soils of Amasiri In Ebonyi State, Southeastern Nigeria

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Abstract
Detailed study on the fertility status and characterization of paddy soils of Amasiri in Ebonyi State, Southeastern Nigeria was carried out. The soil texture varied from loamy sand in the surface layer to clay loam down the profile. Bulk density on oven dry basis ranged between 1.31 – 1.43g/cm^3 and increased with depth. Soil color indicates that the epipedons were darker compared with the sub-surface horizons with reddish characteristics. The soil was slightly acidic, high in organic matter and available phosphorus contents. Cation exchange capacity of the soil was dominated by calcium and magnesium ions with low exchangeable acidity. Micro nutrient element concentration (Zn and B) of the soil ranged from 2.25-7.41 mg/kg and 0.12-0.35 mg/kg respectively.

***Key words**: Heavy metals, Paddy soil, Soil fertility, Soil morphology.*

Introduction

The capacity of soils to sustain biological productivity and diversity, maintain environmental quality and promote plant and animal health is important in assessing soil health (Onweremadu and Oti, 2005). Characterization of soils especially as it relates to elemental distribution in soils provide useful information for assessment and monitoring of the behavior and fertility status of these soils. Again, such studies help to predict the suitability of soils for agricultural and non agricultural uses.

Amasiri sub-agricultural zone of southeastern Nigeria is one of the major rice producing areas in Ebonyi state, known for soil exploitation activities, as well as farming. Paucity of information on the rice growing soils of this area has been a major constraint on rice production. The climatic and soil requirements for low land rice cultivation in most part of Nigeria have been well documented (Asawalam and Okonkwo, 2006, Smith and Montoginery, 1962), all of which give optimum requirement for its successful cultivation in these areas. In view of this, information on the characteristics of the rice growing soils of Amasiri is needed for planning soil fertility research for sustainable exploitation of the fragile paddy soils of the area. The objective of the study was therefore to characterize the paddy soils of Amasiri in Ebonyi State.

Materials and methods

Study Area

Amasiri in Ebonyi State of Southeastern Nigeria is located between the Latitude $5^0$50 and 5^0 56^1 N, and Longitude $7^0$53 and $8^0$54' E. Soils are derived from mixture of Nkporo shale and Afikpo sandstone within the tropical rainforest zone of the southeastern Nigeria. It has an average annual rainfall of about 2250 mm and mean monthly temperature varying between 28^{o}C to 30^{o}C (Ofomata, 1975). Farming is a major socio-economic activity in the area. Occasional grazing by the Hausa-Fulanis is also evident. Land clearing is by slash-and-burn technique while soil fertility regeneration is by bush fallowing whose length has decreased due to anthropogenic activities.

Field Studies

Four representative rice farms were selected at random for the study. One profile pit was dug in each of the farms, the profile pits were described using FAO, (1998) guidelines and samples were collected according to horizons. Core samples were collected for bulk density determination. The soil samples were air dried, crushed and sieved through a 2 mm sieve.

Laboratory Analysis

Particle size distribution was determined by hydrometer method (Gee and Or, 2002). Bulk density was determined using core method (Grossman and Reinsch, 2002). Soil pH was determined using 1:2.5 soil – liquid (water) ratio (Thomas, 1996). Organic carbon was measured by wet digestion method (Nelson and Sommers, 1990). Available P was determined using Bray-P 2 method (Olsen and Sommer, 1982). The soil exchangeable bases were determined by the neutral ammonium acetate procedure. Exchangeable acidity was measured in lN KCl (Mclean, 1965). Total nitrogen was determined by Kjeldah digestion method (Bremner and Mulvaney, 1982). Heavy metals determination was carried out with a mixture of concentrated $HClO_4$ and HNO_3 at a 2:1 ratio and metals extracted with 0.5M HCl (Lacatus, 2000). Aliquots were measured using Atomic Absorption Spectrophotometer. Soil color was determined with munsell color chart. Total porosity was calculated using $TP = 1 - \ell_{b/}\ \ell_s \times 100$ where ℓ_b = bulk density (g/cm^3), ℓ_s = particle density (2.65g/cm^3).

Data Analysis. Data generated were subjected to mean and coefficient of variation analysis using SAS computer software version 8.2 (SAS Institute, 2001). The coefficient of variation was ranked according to the procedure of (Aweto, 1982) where Cv $\leq$ 25% = low variation, Cv $\geq$25 $\leq$ 50% = moderate variation, Cv >50 $\leq$100% = high variation..

Results and Discussion

Particle size distribution

The particle size distribution of the soil showed that the sand fraction ranged between 556.20 – 708.30 g/kg, constituting 55.62-70.83% of the mineral fractions of the soil (Table1). Low variation was observed in the sand content of the soil. Clay fraction varied from 206.20 – 258.90 g/kg while the silt fraction constituted 8.55-15.15% of the particle size distribution of the soil. In all the paddy farms studied, clay fraction increased with depth, with the argillic horizon containing the highest amount. Low clay content of the surface horizons could be due to sorting of soil materials by biological and /or agricultural activities, clay migration or surface erosion by runoff or combination of these (Malgwi *et al*., 2000, Ojanuga, 1975). Chikezie *et al*., (2009), Idoga and Azagaku (2005) reviewed that increased in clay content of soil with depth may be the consequence of eluviations - illuviation processes as well as contributions of the underlying geology through weathering.

Silt-clay ratio

Silt-clay ratio of the soil indicated that the surface horizons had high values relative to the sub-surface horizons which may be as a result of the deposition of materials on the soil surface by water used for low land rice cultivation. However, the average values of the silt-clay ratio ranged between 0.47-0.99 indicating the advanced stage of weathering of the parent material from which the soils developed. According to Onweremadu *et al*., 2007, silt-clay ratio reflects the weathering stage of parent materials of soils. The variations in physical properties of soils showed that silt-clay ratio had moderate (cv $\geq$25 $\leq$ 50%) to high (cv > 50%) in the four different paddy farms studied

Soil color

From the results, it was ascertained that the epipedons were darker while most of the sub-surface horizons possessed reddish characteristics, revealing morphological differences in horizons of soils of similar lithology. The dark color observed in the surface horizons may be a reflection of high organic matter recorded in these horizons. Onweremadu and Oti, (2005), and Foth, (1984) reviewed that white soils usually have low native fertility, and dark soil color is related to high organic matter content of the soil. Apart from soil fertility evaluation, soil color can be used to classify soil (soil survey staff, 2003) and assess soil drainage (Foth, 1984). The effect of usually dark brown or black soil organic matter on soil color is important not only for soil classification purposes, but also for ensuring good thermal properties, which in turn contribute to soil warming and promote biological processes (Schulze *et al*., 1993). Soil color is a cheap indicator of soil quality which provides valuable clues to the nature of other soil properties and conditions.

Bulk density and Soil porosity

The average bulk density of the soil varied from 1.31-1.43 g/cm^3 (Table 1). Bulk density increased with depth in all the farms studied. This finding corroborates with those of Onweremadu *et al*., (2007) and Chikezie *et al*., (2009). Low bulk density reported in the soil may be a consequent of organic matter content of the soil. Akamigbo, (1999) reported that low soil organic matter was responsible for increased bulk density in cultivated soils of Southeastern Nigeria. Within the profiles, possibility of migrating clay filling up the pore spaces in the horizons of illuviation may be account for the high bulk density values in the sub-surface horizons. Moreover, frequent cultivation of land made the soil loose and ultimately contributed for the low density in these layers. Results on bulk density were less than the critical limits for root restriction (1.75 – 1.85 g/cm^3) (soil survey staff, 1996) indicating the potential of the soil to support rice production. The percentage total porosity of the soil ranged between 46 - 50%, with the surface horizons containing higher pore spaces. Khan *et al*., (2006) reported similar trend in selected paddy soils under long-term intensive fertilization. High pore spaces recorded in the surface horizons may be attributed to loosening of soil materials during puddling/cultivation of soil

Soil pH

Soil reaction showed slightly acidic condition which is ideal for rice production and encourages nutrient availability, indicating little or no incidence of leaching of nutrient elements down the profile. Ideally paddy soils experience changes in soil reaction due to fluctuating high water table. Onweremadu *et al*., (2007) reported similar soil reaction in selected wetland soils of Nigeria. The variation in the pH of the soil is very little, with coefficients of variation of 0.69 – 2.38%.

Organic matter and Total nitrogen

Organic matter content of the soil varied from 30.40 t0 39.20 g/kg as shown in Table 2. High organic matter content of the soil could be attributed to climate and management practices common in the area. High coefficient of variation (cv > 50%) was recorded in all the soils of the rice farms studied. Organic matter is one of the important parameters used in judging soil quality and productivity. It has been reported to have significant positive influence on soil pH, cation exchange capacity, color, buffering capacity, base saturation and water holding capacity (Akamigbo, 1999) and effective cation exchange capacity (Onasanya, 1992). For most low activity clay of the tropical soils, the organic matter is the major exchange site for the basic nutrient cations in the soil. In view of this, steps should be taken to increase the organic matter content of the soil, so as to improve agronomic potentials of soils. This can be achieved through appropriate land use type and use of organic residues to conserve, maintain favorable soil temperature and encourage biological activities of soil organisms.

Table 1: Physical properties of soil

Horizon	Depth (cm)	Sand g/kg	Silt g/kg	Clay g/kg	Tex.	SCR	Soil color	BD g/cm^3	% MC	% Total porosity
Profile1										
AP	0-15	869.60	84.20	46.20	LS	1.82	7.5YR3/3 DB	1.09	24.48	51.00
AB	15-45	669.60	84.20	246.20	SCL	0.34	5YR5/4 RB	1.21	27.94	54.00
Bt	45-75	489.60	184.20	326.20	CL	0.57	2.5YR Red	1.63	27.86	38.00
Mean		**676.30**	**117.50**	**206.20**		**0.90**		**1.31**	**26.76**	**47.67**
Cv %		19.54	49.14	69.94		88.50		27.61	7.38	17.84
Profile 2										
AP	0-18	749.60	164.20	86.20	LS	1.91	5YR3/2 DRB	1.00	31.42	62.00
AB	18-46	729.60	64.20	206.20	LS	0.31	5YR5/4 RB	1.59	56.20	40.00
Bt	46-80	509.60	144.20	346.20	CL	0.42	10YR YB	1.69	24.27	36.00
Mean		**662.90**	**124.20**	**212.80**		**0.88**		**1.43**	**37.29**	**46.00**
Cv %		16.36	11.46	44.40		90.97		26.52	42.08	30.43
Profile 3										
AP	0-12	707.60	146.20	146.20	LS	1.00	7.5YR 3/3 DB	1.29	21.90	51.00
AB	12-38	747.60	46.20	206.20	LS	0.22	2.5YR4/3 RB	1.37	27.16	48.00
Bt	38-75	669.60	64.20	268.40	SL	0.24	10YR5/4DYB	1.55	27.20	41.00
Mean		**708.30**	**85.50**	**206.90**		**0.47**		**1.40**	**25.42**	**46.67**
Cv %		5.51	62.34	29.53		94.71		9.23	61.56	11.00
Profile 4										
AP	0-16	629.60	204.20	166.20	SL	1.23	10YR3/4DYB	1,10	46.79	59.00
AB	16-45	549.60	186.20	264.20	L	0.71	2.5YR5/6Red	1.40	39.62	47.00
Bt	45-75	489.60	164.20	346.20	CL	0.47	7.5YR5/4B	1.50	42.64	44.00
Mean		**556.20**	**151.50**	**258.90**		**0.80**		**1.33**	**43.02**	**50.00**
Cv %		8.51	6.00	34.81		48.97		15.39	56.23	15.87

SCR = silt clay ratio, BD = Bulk density, MC = moisture content, DB = dark brown, RB = reddish brown, DRB = dark reddish brown, DYB = dark yellowish brown, YB = yellowish brown, B = Brown, LS = loamy sand, SCL = sandy clay loam, CL = clay loam, L = loam, SL = sandy loam. Cv = Coefficient of variation, cv $\leq$ 25% = low variation, cv $\geq$25 $\leq$ 50% = moderate variation, cv >50 $\leq$100% = high variation.

In all the farms studied, organic matter decreased with increased depth and could be a reflection of the bulk density of the soil. From the results, it was observed that soil organic matter had significant influence on soil color, bulk density, nutrient element concentration and cation exchange capacity of the soil. According to FAO, (2005), soil organic matter-the product of on-site biological decomposition affects the morphological, chemical and physical properties of the soil and its overall health. Total nitrogen content of the soil was within the range of critical level of 0.15 % (1.5 g/kg) for optimum crop production in the tropics indicating the inherent ability of the soil to support rice production. Moderate (cv $\geq$25 $\leq$ 50 %) to high (cv > 50%) coefficient of variation was recorded in total nitrogen contents of the soils (Table 2)

Available Phosphorus

Available P content of the soil was high with the surface horizon containing the highest amount. The high concentration of available P in the soil may be a reflection of soil pH and organic matter content of the soil. Halvin *et al*, (2005) and Idigbor *et al*., (2008) reported that P availability in most soils is at maximum when soil pH is between 6.0 - 6.5. Considering the critical level of P in soils of southeastern Nigeria which is 15 mg/kg (Enwezor *et al*., 1990), the soils of Amasiri which tested high far above the critical level is endowed with P and may not require phosphate fertilizer application for increased rice yield.

Exchangeable bases and cation exchange capacity.

Total exchangeable bases (TEB) which ranged between 4.31- 6.34 cmol/kg (Table 2) was dominated by calcium (Ca^{+2}) and magnesium (Mg^{+2}) ions. However, the Ca^{+2} and Mg^{+2} levels of the soil were higher than the critical levels of 2.00 and 1.20 cmol/kg respectively (Halvin *et al*., 2005), indicating the potentials of the soil to support crop production. The effective cation exchange capacity of the soil was dominated by the exchangeable bases showing the capacity of the soil to retain nutrient elements. Low exchangeable acidity of the soil may be a consequent of the soil reaction and base saturation which have significant influence on soil acidity.

Micro nutrient elements

The micronutrient contents of the soil did not follow any definite sequence in their distribution within the profile. Jalai *et al*, (1989) reported a decreasing trend of zinc with depth in some soils of Kashmir. Using critical available Zn level of 0.8 mg/kg (Kparmwang *et al*., 2000) or critical range of 0.2 - 2.0 mg/kg, zinc deficiency was not a problem in the soil as have been reported for most Nigeria soils (Udo and Fagbemi, 1979, Kparmwang *et al*., 2000). However, low boron content of the soil is a reflection of organic matter content of the soil revealing the influence of soil organic matter on micronutrients that occur predominantly as cations. According to Horng-yuh *et al*., 2009, boron availability in soil is highest in acid soils, and decreases as soil pH increases due to sorption unto soil colloid or development with soil organic colloid. Boron distribution in the soils studied showed high variations (cv > 50%) in all the profiles while that of zinc had low variation with exception of the fourth profile (Table 2).

Conclusion

Soils were slightly acidic and high in base saturation, available phosphorus and organic matter. The effective cation exchange capacity of the soil was dominated with exchangeable bases with low exchangeable acidity. Generally, soils of the study area possessed certain agronomic potentials for sustainable crop production and may need little fertilizer application.

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Table 2: Chemical properties of soil

Horizon	Depth (cm)	pH (H_2O)	OM g/kg	Av.P mg/kg	TN g/kg	Ca	Mg	K	Na cmol/kg	TEB	EA	ECEC	% BS	Zn mg/kg	B mg/kg
					Profile1										
AP	0-15	6.26	51.50	49.00	2.20	3.20	2.06	0.12	0.16	5.54	0.80	6.34	87.38	7.94	0.17
AB	15-45	6.15	21.00	18.90	1.20	2.40	1.63	0.02	0.20	4.25	1.40	5.65	75.22	5.12	0.13
Bt	45-75	6.06	18.70	15.00	1.20	1.92	0.98	0.10	0.14	3.14	1.20	4.34	72.35	6.52	0.04
Mean		**6.16**	**30.40**	**27.63**	**1.50**	**2.51**	**1.35**	**0.41**	**0.15**	**4.31**	**1.13**	**5.44**	**78.31**	**6.52**	**0.12**
CV %		1.63	60.23	67.34	38.59	25.85	44.35	98.49	24.50	27.85	26.91	78.05	9.89	21.64	55.90
					Profile 2										
AP	0-18	6.25	60.20	52.15	2.80	2.88	2.49	0.71	0.11	6.19	0.90	7.09	87.31	3.62	0.06
AB	18-46	5.99	39.90	30.00	1.40	1.92	1.65	1.09	0.15	4.81	1.00	5.81	82.79	3.40	0.24
Bt	46-80	6.02	11.90	21.92	1.10	1.20	1.01	0.98	0.16	2.35	1.01	3.36	69.94	6.69	0.73
Mean		**6.08**	**37.30**	**34.69**	**1.80**	**2.00**	**1.72**	**0.95**	**0.14**	**4.45**	**0.97**	**5.42**	**80.01**	**4.57**	**0.34**
Cv %		2.38	65.02	45.12	50.18	42.08	43.10	20.91	18.90	43.72	6.27	7.18	11.26	6.76	65.20
					Profile 3										
AP	0-12	6.01	67.40	41.10	3.10	2.88	2.47	0.08	0.17	5.60	0.51	6.11	92.65	9.17	0.03
AB	12-38	6.03	39.10	24.00	1.30	2.88	2.49	0.09	0.18	5.64	0.36	6.00	94.00	7.94	0.48
Bt	38-75	6.09	11.10	19.21	1.20	1.44	1.20	0.08	0.16	2.88	0.25	3.13	92.00	5.72	0.54
Mean		**6.04**	**39.20**	**20.77**	**1.90**	**2.40**	**2.05**	**0.08**	**0.17**	**4.71**	**0.37**	**5.08**	**92.89**	**7.41**	**0.35**
Cv %		0.69	71.81	70.28	56.32	34.63	36.05	8.84	5.88	33.60	35.50	33.27	1.10	23.83	79.82
					Profile 4										
AP	0-16	6.05	51.50	42.00	2.50	4.80	4.17	1.10	0.14	10.21	0.20	10.41	98.07	4.00	0.46
AB	16-45	6.09	35.80	35.00	1.50	2.40	2.04	0.86	0.15	5.45	0.20	5.65	96.46	1.62	0.18
Bt	45-75	6.14	10.80	26.10	1.00	1.68	1.42	0.11	0.14	3.35	0.30	3.65	91.18	1.12	0.07
Mean		**6.09**	**32.70**	**34.37**	**1.70**	**2.96**	**2.54**	**0.69**	**0.14**	**6.34**	**0.23**	**6.57**	**95.44**	**2.25**	**0.24**
Cv %		0.74	62.73	23.20	45.00	55.19	56.81	75.06	5.05	55.09	25.16	52.87	3.79	68.40	84.63

TN = Total nitrogen, OM = Organic matter, Ca = Calcium, Na = Sodium, Mg = Magnesium, EA = Exchangeable acidity, K = Potassium, Av.P = Available phosphorus. TEB = Total Exchangeable bases, ECEC = Effective cation exchange capacity, Zn = Zinc, B = Boron. Cv = Coefficient of variation, cv $\leq$ 25% = low variation, cv $\geq$25 $\leq$ 50% = moderate variation, cv >50 $\leq$100% = high variation.