NIGER AGRIC. J. 37 (2006) 91-97

PROPERTIES OF SOME RICE GROWING SOILS IN SOUTH EASTERN NIGERIA BY

D. O. Asawalam and E. Okonkwo

Department of Soil Science & Agroclimatology

Michael Okpara university of Agriculture, Umudike

PMB 7267, Umuahia, Abia State, Nigeria

asawaldo@yahoo.com

ABSTRACT

Selected rice-growing soils in Abia, Ebonyi, Imo, Anambra and Enugu states were characterized based on some physical and chemical properties. Properties evaluated include texture, porosity, available water capacity, hydraulic conductivity, soil reaction, total exchangeable bases, exchangeable acidity, effective cation exchange capacity, and base saturation, organic matter, nitrogen and phosphorus. Results showed that the soils varied in texture from sandy loam to loam and to silty loam. Total porosity ranged from 36.2 to 60.9% while bulk density varied from 1.04 to 1.60 g cm^{-3}. Available water capacity and hydraulic conductivity varied slightly from one location to another. The soils are strongly to slightly acidic with moderate to high levels of organic matter contents. Effective cation exchange capacity and base saturation were moderate to high. The soils have low to moderate levels of nutrient concentrations.

INTRODUCTION

Rice is an important food crop in Nigeria and greater part of the quantity consumed Locally is imported. In an attempt to reduce the dependence on heavy importation, the Federal Government of Nigeria initiated several agricultural programs, including the presidential initiative in rice. A large area of inland valley soils developed over shale in the middle belt and southeastern Nigeria are known to support small scale rice production. It is estimated that about 610,000ha are planted to rice crop (Nyanteng, 1987). Important rice growing communities in southeastern Nigeria include Uboma in Imo State, Bende in Abia State, Akaeze and Abakaliki in Ebonyi State, Adani in Enugu State and Omor in Anambra State. Very little is known about the physico-chemical properties of these soils that have sustained rice production for centuries. In order to boost local production and achieve the goal of the presidential initiative on rice, information on the characteristics of the soils already supporting rice production is necessary. The objective of this study is to determine and document the physical and chemical properties of the rice growing soils in southeastern Nigeria.

MATERIALS AND METHODS

The study was conducted at Michael Okpara University of Agriculture, Umudike. Soils for this study were collected from Bende, Uboma, Akaeze, Omor and Adani located in Abia, Imo, Ebonyi, Anambra and Enugu states respectively. Representative samples were obtained at depths of 0 15cm and 15 30 cm using soil auger. Soil samples were collected in at least three spots in each location. The samples collected at each location were bulked by depth. The soil samples were air-dried and made to pass through 2mm sieve for particle size and chemical analysis. The particle size analysis was carried out by Bouyoucos (1951) hydrometer method, using sodium hexametaphosphate as dispersant. Soil pH in 1: 2.5 soil-to-water ratio, was determined using a combined electrode pH meter. Organic carbon was determined by the dichromate wet oxidation method (Walkley and Black 1934). Total nitrogen was determined by the macro-kjeldahl method of Black. (1965). Available phosphorus was determined by Bray and Kurtz (1945) number II method. Exchangeable cations in the soils were extracted with neutral ammonium acetate. Exchangeable Na and K were measured with flame photometer, while Ca and Mg were determined by EDTA titration method. Exchangeable acidity was determined by the method of Mclean (1965). Total Exchangeable Bases (TEB) was obtained by the summation of the exchangeable bases (Na, K, Ca and Mg). Effective Cation Exchange Capacity (ECEC) was calculated as the sum of exchangeable metallic cations and the exchangeable acidity. Base saturation was determined by multiplying the quotient of TEB to ECEC by 100.

Also, core samples were collected at each site for determinaion of hydraulic conductivity, bulk density, total porosity and available water. Hydraulic conductivity of saturated soils was determined by the constant head method of Klute (1965). The bulk density was determined by the core method of Black (1965). Total porosity was calculated as Bulk density / particle density x . 100

Percentage Water Content at Saturation (WCS) was calculated as follows: %WCS = Weight of wet soil / weight of dry soil x 100

Percentage Water Content at Field Capacity (WCF) was determined by allowing the saturated soil to freely drain for two days after which the soil was weighed to determine the moist weight. The soil was thereafter dried and weighed again. The % WCF was calculated as weight of moist soil / weight of dry soil x 100. The analytical data obtained were subjected to analysis of variance (ANOVA). Means separation was carried out by Fisher's Least Significant Different at 5% probability.

RESULTS AND DISCUSSION

Physical Properties

The physical properties of the soil are shown in table 1. The texture of the soils ranged from loam at Bende and Uboma to sandy loam at Akaeze and silt loam at Omor and Adani. Sand dominated the topsoils of Bende and Uboma being 52.3% and 67.4% respectively and decreased slightly at the lower depth. Percentage sand was significantly ($P<0.05$) higher at Uboma than at the other locations at both depths. The texture of the soils at Adani and Omor were dominated by the silt fraction. The percentage silt were statistically similar at both locations but significantly ($P<0.05$) higher than the values recorded at the other locations. With regard to clay content, the soils were similar at the top 0 15cm depth. At the 15 30cm soil depth, clay content was significantly higher at Akaeze relative to Uboma, Omor and Adani.

The bulk density ranged between 1.10g/cm^3 and 1.56g/cm^3 in the topsoils of the areas studied, while values ranged from 1.04g/cm^3 to 1.60g/cm^3 for the sub-surface horizons. The bulk density of Akaeze soil (1.56g/cm^3) was significantly ($P<0.05$) higher than that of the other soils at the 0 15cm depth. At the 15 30cm depth, the bulk density of Akaeze and Omor soils were significantly ($P<0.05$) higher than Bende and Uboma soils. High values of total porosity were obtained at Bende and Omor surface and sub-surface horizons. At these locations, total porosity ranged between 60.7% and 53.7% for topsoil and between 60.9% and 36.2% for sub-soils respectively. At the 0 15cm soil depth, total porosity in Akaeze, Adani and Uboma soils were significantly ($P<0.05$) lower than the values at Omor and Bende.

The percentage water content at saturation (WCS) of the soils studied was highest at Bende surface and sub-surface soils. Lowest value was obtained in Adani soil at the 0 15cm soil depth. The value obtained at Bende was significantly ($P<0.05$) higher than that at the other locations. Results (Table 1) showed that WCS was similar in Adani, Omor and Akaeze soils.

Table 1. Physical properties of some rice growing soils in southeastern Nigeria.

Location	Sand	Silt	Clay	BD	TP	WCS	WCF	Ksat	Texture
	%			g/cm^3	%			cm/min	
Depth = 0 – 15 cm									
Bende	52.33	32.07	15.60	1.10	60.67	80.33	50.07	0.023	Loam
Uboma	67.37	19.03	13.63	1.24	53.10	62.87	49.42	0.017	S/loam
Akaeze	42.23	39.50	18.27	1.56	41.01	42.23	34.57	0.002	Loam
Omor	25.37	64.37	10.27	1.23	53.73	50.57	41.53	0.005	Si/loam
Adani	18.03	68.37	13.60	1.42	46.43	41.27	36.67	0.004	Si/loam
Lsd 0.05	8.86	5.94	5.58	0.34	11.92	15.69	11.31	0.021	
Depth = 15 – 30 cm									
Bende	43.00	38.07	18.93	1.04	60.87	73.23	68.23	0.036	Loam
Uboma	63.37	26.37	10.30	1.39	47.53	41.77	41.20	0.024	S/loam
Akaeze	35.57	41.50	22.93	1.61	44.37	31.70	31.73	0.003	Loam
Omor	26.70	66.37	10.27	1.69	36.23	38.17	34.17	0.003	Si/loam
Adani	16.03	68.37	15.60	1.43	44.80	41.73	35.57	0.003	Si/loam
Lsd 0.05	9.23	12.25	4.74	0.35	15.03	17.31	13.73	0.045	

BD = Bulk density; TP = Total porosity; WCS = Water content at saturation; WCF = Water content at field capacity; Ksat = Saturated hydraulic conductivity.

At the 15 30cm depth, WCS was significantly ($P<0.05$) higher in Bende soil relative to the other soils. High values of water content at field capacity (WCF) were recorded at Adani top and sub-soils. In this location, percentage WCF ranged between 50 and 68.2% as compared to Akaeze where percentage WCF were 34.6 and 31.7% at surface and sub-surface horizons respectively. The percentage WCF of the sub-soils of the five locations did not differ statistically.The available water capacity was highest at Bende, at both top and sub-soils values ranged between 20.97 and 25.67%. The lowest values were recorded at Adani surface soils and Omor sub-soils, with values of 12.60 and 15.63% respectively. This is a reflection of the high percentage clay recorded at Bende and low percentage clay obtained at Adani and Omor. Soils that have high clay contents have more water storage capacity (Gupta and O'toole, 1986). The saturated hydraulic conductivity (Ksat) was greater in the surface and sub-surface soils of Bende with values ranging between 0.023cm/min and 0.036cm/min respectively. The analytical results showed no significant difference in Ksat values among the locations at 0 15 and 15 30cm soil depths.

Chemical Properties

Some chemical properties of the soils are shown in Table 2. The rice growing soils are generally acidic. The pH in water ranged from 4.78 at Adani to 6.36 at Bende at the surface and 4.94 to 6.43 at the sub-surface horizons. The high percentage of organic matter obtained at Bende, Uboma and Akaeze top and sub-soils resulted in the reduced acidity of the soils recorded in these locations. The accumulation of organic matter in the soil due to the decomposition of residues from the vegetation cover should have led to reduced acidity as a result of complexion of soluble Aluminium by organic matter (Hue and Amien, 1990; Aluko, 2001). The organic matter contents ranged from 1.81 to 5.57% in the topsoils, while the values ranged from 1.58 to 4.76% for the sub-surface horizons. Reduced microbial activities due to poor soil aeration is one of the reasons for the generally high organic matter contents of wetland soils (Wild, 1958). Exchangeable acidity (EA) was highest at Uboma location. EA in the surface soils of Bende, Adani, Akaeze and Omor were statistically similar, but significantly ($P < 0.05$) lower than the values in Uboma soil. The effective cation exchange capacity (ECEC) ranged between 5.27 20.50 and 4.65 14.07cmolkg^{-1} in the surface and sub-soil horizons of Bende and Akaeze soils respectively. According to Fagbami (1994) cited by Aluko *et al,* (2001), values below 10cmolkg^{-1} are considered marginally adequate, while ECEC values above 20 cmolkg^{-1} show high suitability for crop production. The base saturation (BS) values were highest in Bende and Omor, ranged between 91.63 and 88.23%; and 82.27 and 83.60% respectively as compared to the low values of 59.77% recorded at Adani surface soil and 48.73% obtained at Uboma sub-soil. The high base saturation of the soils is due to their equally high TEB, which have relatively high Ca, Mg and K. The relatively high ECEC and base saturation of the soils may be responsible for sustaining the traditional cultivation of rice in these areas.

Table 2. Some Chemical properties of rice growing soils in southeastern Nigeria

Location	pH (water)	pH (KCl)	Org. C (%)	EA	TEB	ECEC	BS (%)
				cmol kg $^{-1}$			
			Depth = 0 – 15 cm				
Bende	6.36	5.21	3.23	1.73	18.77	20.05	91.63
Uboma	5.30	3.63	2.70	4.87	7.50	12.37	61.03
Akaeze	5.31	3.80	2.66	2.60	5.55	8.15	66.83
Omor	5.26	3.74	1.11	2.67	12.43	15.09	82.27
Adani	4.78	3.82	1.05	2.07	3.20	5.27	59.77
Lsd 0.05	0.55	0.42	0.63	1.46	2.14	2.24	17.41
			Depth = 15 – 30 cm				
Bende	6.43	5.26	2.19	1.43	12.19	13.62	88.23
Uboma	5.57	3.56	2.76	5.53	5.44	10.97	48.73
Akaeze	5.33	3.68	2.16	3.37	6.57	9.94	66.07
Omor	5.45	3.77	1.19	2.33	11.76	14.07	83.60
Adani	4.94	3.73	0.92	1.53	3.05	4.65	66.87
Lsd 0.05	0.37	0.30	1.60	0.84	4.42	4.20	15.78

EA = Exchangeable acidity; TEB = Total exchangeable basis ; ECEC = Effective cation exchange capacity; BS = Base saturation.

Nutrient Concentrations

Table 3 shows the nutrient concentrations of the soils. The nitrogen content of the soils is generally low, but with higher concentration in the soils where the organic matter content is high. High nitrogen values were obtained at Bende and Uboma surface and sub-surface soils. All the rice growing soils in the area under investigation had available P contents greater than 10 mg kg $^{-1}$. Soils with P values below 10 mg kg $^{-1}$ are generally considered marginally suitable while soils with P values greater than 20 mg kg $^{-1}$ are considered highly suitable (FAO 1976). Nitrogen and P are organic matter dependent and are released into the soils as organic matters mineralize (Agboola and Corey, 1973). Potassium is a key element in the fertilization of agricultural crops. Potassium status of Bende and Akaeze top soils and Uboma and Bende sub-soils were greater than 0.2 cmolkg $^{-1}$ given as critical levels of exchangeable K (Kyuma *et al.*, 1986). The level of exchangeable Ca in Benede Akaeze, Uboma, Omor and Adani ranged from 1.73 to 11.07 cmolkg $^{-1}$. The concentrations of 11.07 and 10.53 cmolkg $^{-1}$ obtained respectively at the surface and sub-surface horizons of Bende soil are high and unexpected. Most of the values of Ca obtained were above 4 cmolkg $^{-1}$ which is regarded as the lower limit for fertile soils (Kyuma et al., 1985). The contents of exchangeable Mg ranged from 1.07 to 6.93 cmolkg $^{-1}$. These values were above 0.5 cmolkg $^{-1}$ regarded as the critical level (Landon, 1984).

Table 3. Nutrient concentrations in some rice growing soils in southeastern Nigeria

Location	Total N (%)	Avail. P (mg kg $^{-1}$)	Ca	Mg	K	Na
			cmol kg $^{-1}$			
			Depth = 0 – 15 cm			
Bende	0.31	32.50	11.07	6.93	0.65	0.12
Uboma	0.12	36.00	4.80	2.40	0.20	0.09
Akaeze	0.07	43.67	3.47	1.73	0.25	0.10
Omor	0.05	20.67	8.27	3.73	0.10	0.33
Adani	0.06	22.67	1.73	1.20	0.10	0.17
Lsd 0.05	0.07	ns	1.73	1.22	0.14	0.08
			Depth = 15 – 30 cm			
Bende	0.25	23.67	10.53	4.53	0.36	0.10
Uboma	0.09	22.90	3.33	1.87	0.16	0.08
Akaeze	0.07	31.43	4.00	2.27	0.20	0.11
Omor	0.06	17.33	7.73	3.60	0.09	0.28
Adani	0.04	21.50	1.87	1.07	0.07	0.22
Lsd 0.05	0.06	ns	2.19	1.32	0.07	0.12

Conclusion

The rice growing soils in Southeastern Nigeria showed some similarities and minor differences in their physical and chemical properties. Their textures vary from sandy loam to silty loam. They have fairly high water holding capacity. Chemically, the soils are generally acid with low to moderate level of ECEC and moderate to high levels of organic matter content and base saturation. In terms of fertility status, the soils have low to moderately high levels of nutrient concentrations. Other soils with similar characteristics can support rice production. Improving the fertility status of these soils will sustain enhanced rice production in the study area.

REFERENCES

Agboola, A. A. and Corey, R. B. (1973). The Relationship between Soil pH, Organic Matter Available Exchangeable Potassium, Calcium, Magnesium and Nine Elements in the Maize Tissue. *Soil Science*. 15: 367 375.

Aluko, A. P. (2001). Impact of Plantation Forestry on the Nutrient Status In Degraded soils for Environmental Management At Onne, Rivers State Nigeria. In proceedings of the 27th Annual conference of the Forestry Association of Nigeria, Abuja FCT, Nigeria. Pp. 109 115.

Aluko, A. P., Owonubi, J. J. and Fagbenro, J. A. (2001). Physio-chemical Properties and Potentials of some Wetland Soils of the Mangrove Ecosystem for Sustainable Forest Trees Establishment. Pp 237 240. In: Management of wetland soils for sustainable Agriculture and environment Proceedings of the 27th Annual Conference of the soil Science Society of Nigeria. Nov. 5 9, University of Calabar.

Black, C. A. (1965). Methods of Soil Analysis Agronomy No. 9. America Society of Agron. Madison Wisconsin.

Bouyoucos, G. H. (1962). Hydrometer method improved for making particle size analysis of soils. Agronomy Journal 53: 464 465.

Bray, R. H. and L. T. Kurtz (1945). Determination of total organic and Available phosphorus in soils. *Soil Science.* 59: 39 45.

FAO, (1976). A Frame Work of land Evaluation. FAO Soils Bulletin. 32 Rome FAO

Gupta, P. C. O'toole, J. C. (1986). Upland Rice: A Global Perspective. International Rice Research Institute, Los Banos Philippines. Pp 42 60.

Hue, N. V. and Amien, I. N. (1990). Alumminium detoxification with green manure. Communication in soil science and plant Analysis 20: 1499 1511.

Klute, A. (1965). Laboratory Measurements of hydraulic conductivity of saturated soils. In: methods of soil Analysis. C. A. Black (ed), Agron. No. 9. part 1. American Society of Agronomy, Madison, Wisconsin.

Kyuma, K., Rosaki, T. and Juo, A. S. R. (1986). Evaluation of the Fertility of the Soils. In: A. S. R. Juo and Low (ed). The Wetland Soil and Rice in Sub Sahara Africa. Proceeding in International Conference of Wetland Soil Utilization for Rice Production in Sub-Sahara Africa.

Landon, J. R. (1984). Tropical Manure Booklet. Handbook for Soil Survey and Agricultural Land Evaluation in the Tropics and Sub tropics.

Mclean, E. O. (1965). Aluminium. In: Methods of soil analysis. C. A. Black (ed), Agron. No. 9. part 2. pp 986 994 . American Society of Agronomy, Madison, Wisconsin.

Nyanteng, V. K. (1987). Rice Situation in West Africa Consumption, Inputs and Production with Projections to the Year 2000. WARDA, Monrovia Liberia.

Walkley, A. and Black, I. A. (1934). An examination of the Degtjareff method for determining soil organic matter and a proposed chromic acid acid titration method. *Soil. Science.* 37: 29 38.

Wild, S. A. (1958). Forest Soils, Their Properties and Relation to Silviculture Ronald Press Company N. Y. 537.