FERTILITY CAPABILITY CLASSIFICATION OF SOME SOILS WITH AQUIC MOISTURE REGIME IN DELTA STATE, NIGERIA

Egbuchua, C.N
Department of Agronomy, Delta State University
Asaba Campus Asaba, Delta State, Nigeria.
Email: egbuchuacn@yahoo.com
Phone: 08025775887

Abstract

Fertility Capability Classification (FCC) of some soils with aquic moisture regime in Delta State, Nigeria was investigated. Three mapping units namely: Mangrove swamps, river flood plain, and inland valley located at Burutu, Ossissa and Okwagbe were used for the study. Soil samples were collected from 0--25 and 25—60 cm depth from each of the mapping units and analyzed for some of their physico - chemical properties. The fertility capability classification system in which Types, Substrate Types and Modifers were used in classifying the soils based on the results of the physico- chemical properties evaluated. The results of the study showed that the texture of the soils ranged from clayey in the mangrove swamps to loamy and sandy loam in the river flood plain and inland valleys soils respectively. The soils were strongly to slightly acidic (4.6 – 6.3) in water and KCL solution. The values of organic carbon ranged from 5.58 – 7.65 gkg^{-1} in the mangrove swamp soils and 2.20 – 3.18 gkg^{-1} in the river flood plain and inland valley soils. Available phosphorus were low (3.20 – 7.50 mgkg^{-1}). The values of total nitrogen were low (0.95 – 2.24 gkg^{-1}). The exchangeable bases particularly sodium ion was high in the mangrove swamp soils 5.01 – 5.65 Cmolkg^{-1} but low in the river flood plain and inland valley soils (0.17 – 0.18 Cmolkg^{-1}). The percent Base saturation were moderate to high in the river flood plain and mangrove swamp soils (17.3 – 58.8%) and low in inland valley (12.9 – 14.0%). In the application of the FCC system, the soils are characterized by the following fertility indicators: C,O,X,h, g,w, s and for mangrove swamp, soils and L, h, e, k and i for the river flood plain and inland valley soils respectively. The common limiting factors include excessive wetness (w), high acidity (h), low P. content (i), salinity (s) especially with mangrove swamps, and low potassium reserves (k).

Keywords***: Fertility capability classification, and aquic moisture regime***
http://dx.doi.org/10.4314/jafs.v9i2.4

Introduction

Fertility capability classification is a technical system for grouping soils according to the kinds of problems they present for agronomic management (Sanchez et al 1982, Sanchez and Buol 1985). It is based on quantitative top soil and sub-soil parameters directly relevant to plant growth and derived from the class limits of soil taxonomy or from the legend of the FAO/ UNESCO soil map of the world (FAO 1974).

The system was designed specifically to group soils having similar limitations for effective fertility management and, as a guide for the extrapolation of the fertilizer responses based on soil parameters designated as Types, Substrate Types and Modifiers. (Buol and Couto, 1980). The Types describe the texture of plow- layer (surface 20 cm), and it is listed in upper case letters as: S, L, C and O. The Substrate Type, are also listed in upper case letters as S, L, C and R. where, S is for Sandy, L for Loamy, C for Clayey and O, a newly introduced type that indicates organic surface layer in soils. The modifiers are usually indicated in lower case letters such as g, k, h, s, i, and e which depict specific attributes of the soils such as gleying (g), low potassium status (k), high acidity (h), salinity (s) and low CEC(e). (Sanchez *et al;* 1982).

In most developing countries of the world, the fertility capability classification (FCC) system has not been preferably used as an indicative classification along with the more inclusive natural classification system. This is unlike the advanced countries where the system has been used along with data from soil survey reports and soil test to administer effective fertilizer applications that will ensure agricultural land sustainability (Isirimah, 2005). In regions such as Nigeria where soil analysis are inadequate and expensive, it is therefore important that soils are classified in view of their natural occurrence using the fertility capability classification system. Against this background, the FCC system is therefore used in this study to classify soils with aquic moisture regime using the qualitative soil parameters of Types, Substrate Types and modifiers.

Materials and Methods

The study was conducted in Delta State, Nigeria. The State by its geomorphological setting, lies between longitude 6^0 14^1E and latitude 5^0 43^1N of the equator. The State consists of a broad plain that is interlaced by large meandering rivers and underlain by varying degrees of quartzites, granites, gneiss, schists and isolated deposits of amphibolites (Egbuchua, 2007). The climate is of humid tropical that is characterized by a bimodal pattern of rainfall with an annual average of 2,500 mm. The temperature ranges between 25 – 32^0C annually with a relative humidity of about 75%. The general topography is undulating and the soils are mostly developed from unconsolidated sand deposits by tidal influences and characterized by poor drainage, low relief and extensive formation of alluvial plains (Ministry of Land and Survey, 2005). The vegetation is dominated by mangrove fresh water swamp humid forest with plant species such as *Rhizophoracea*, *Avicenneacea*, *Palmae* and pockets of grasses and sedges found all over the places (Obot *et al;* 1997). The land use is typically of crop cultivation based on rain-fed agriculture and fishing especially in the coastal areas and a lot of oil and gas explorations.

Field Work / Survey Methods

A topographic map at a scale of 1:50,000 was used to delineate the entire soil boundaries of the study areas. Air-photo interpretation using air-photos at the scale of 1:10,000 was employed and the main interpretative criteria was the terrain features. Mapping units were established and three representative profile pits dug in each of them, examined and characterized. Representative soil samples were collected from the pedogenetic horizons using small hand trowel into polythene bags and process by drying at air-room temperature of 25 – 27 ^{0} C, and then, crushed, and sieved to pass through a 2 mm sieve mesh and properly packaged in well labeled envelopes for analysis.

Analytical Procedures

The particle size distribution which largely determines the "Types and substrate Types" was done by Bouyocous hydrometer method using Sodium hexameta phosphate as dispersing agent (Gee and Bauder, 1986). Soil pH was determined in a 1:2.5 soil/water and KCl solution using glass electrode pH meter. Organic carbon was determined by the method of Walkley and Black Wet-Oxidation as modified by Nelson and Sommers (1982). Total nitrogen was determined by micro-Kjeldahl digestion method (IITA, 1979). Available phosphorus was extracted with acid fluoride solution using the Bray No 1 method as modified by IITA, (1979). The Exchangeable cations of calcium (Ca), magnesium (Mg), potassium (K) and Sodium (Na) were analyzed in a 1 N neutral ammonium acetate (1 N NH_4OAC) buffered at pH 7 (IITA, 1979). The Ca and Mg in the extract were read in an Atomic Absorption Spectrophotometer (Model 6405 UV Jenway UK), and K and Na in a flame photometer. Cation exchange capacity (CEC) was determined by the ammonium acetate saturation method (IITA, 1979) and the exchange acidity (EA) by 1 N KCl method (Mclean, 1965). The percent base saturation was determined by summation method as, the sum of all exchangeable bases, and exchange acidity divided by CEC, and multiplied by 100.

Table 1: Fertility Capability Classification (FCC) showing texture, chemical and modifiers

Levels	**Meaning**	**Descriptions**
Types	Top soil	Texture of top 20 cm of the soils
S	Sandy	Loamy sand and sand
L	Loamy	< 35% clay
C	Clayey.	> 35% clay
O	Organic	> 20% at 50 cm depth or more
Substrate Types	Sub soil	Texture of top soils within 50 cm of the surface
S	Sandy	Loamy sand and sand
L	Loamy	< 35% clay
C	Clayey	> 35% clay
R	Rocky	Hard layer restricting root growth
Modifiers		
k	Low K contents	K value < 0.2 $Cmolkg^{-1}$
e	Low CEC	CEC < 4 and 7 $Cmolkg^{-1}$
a	Altoxicity	Al > 60% $Cmolkg^{-1}$
h	Acidic	Acidity level 4 – 6.0 in water and KCl
s	Salinity.	> 4 dsm^{-1}
g	Gleying.	Mottles < 2 chroma within 60 cm of soil.
n	Nitric.	> 15% Na saturation of CEC.
i	Low P. reserves.	< 8 $mgkg^{-1}$
c	Cat clay.	pH < 3.5 in water.
%	Slope.	1 – 6% of slope gradient.
w	Ponding.	Excessive water accumulation at 20 cm depth.

Source: Snchez and Buol (1985).

Results and Discussion

Physical Characteristics

The particle size distribution (Table 2), showed that silt contents of the mangrove swamp soils ranged from 33.4% at the top 0 – 25 cm horizon and 31.4% at that lower horizons. The high silt contents have been attributed to low intensity of weathering associated with soils with aquic moisture regimes Moberg and Esu, (1991), and to sediments brought from the adjoining rivers or streams by waves (Aluko *et al;* 2000). The texture of mangrove swamp soils were dominantly clayey at surface and sub-surface horizons with high silt contents of more than 30%. This indicates that the soils are highly sticky and plastic when wet, and cracking when dry. The river flood plain is loamy at the surface, and clay loam at the sub-surface horizons. The mean values ranged from 38.2% for sand, 35% for silt, 26.8% for clay and 1.32 for silt/clay ratios.

The inland valley soils were more sandy with a mean value of 61.2% sand, and have fine clayey sub-soils that were irregularly distributed with depth of profile pits. This is an indication of stratification of the fluvial parent materials of the soils. All the soils can be described as heavy textured due to their clay related contents which accounts for their low permeability. The same observations have been reported by Ahn (1993), and Esssoka and Esu (2001) in their studies on wetland soils in the tropics.

Chemical characteristics

The results of some chemical characteristics of the soils are shown in Table 3. The soil pH in both water and KCL solutions, ranged from 4.6 – 6.1 (H^2O) and 6.1 – 6.3 (KCL) measured. These values are rated as strongly acid to slightly acid. The strong acid condition could be due to the dissociation of strong acidic functional groups in organic matter and the redox products of ferrolysis that is common in wetland soils. Values of electrical conductivity (EC) were quite high in the mangrove swamp soils (15.46 – 15.70 dsm^{-1}) indicating salinization as a major pedogenetic process in the mangrove swamps. The values in the river flood plain and inland valley soils ranged from 0.08 – 0.85 dsm^{-1} which implied that the soils are not saline in nature under drained condition. Organic carbon in the mangrove swamp soils was high (5.58 – 7.65%). This could be attributed to slow decomposition rate of litter materials, high fibrous mangrove rootlets and slow microbial activities (Moorman and Pons 1974, and Egbuchua, 2007).On the other hand, the river flood plain and inland valley soils had low organic carbon contents (2.20 – 3.18%). These could be attributed to erosion effects, continuous cultivation, and seasonal bush burning that is rampant in areas during the harmattan period (Egbuchua, 2007). Total nitrogen was high in the mangrove swamps (1.18 – 2.24%) which exceeds 0.2% established by FMANR, (1990) as the critical value where response to fertilizer application is likely. The high content of total nitrogen reflected by the organic carbon contents of the soil, which contributes over 75% of soil organic nitrogen (Egbuchua, 2007). Available phosphorus across the pedons were general low and this ranged from 3.80 – 5.40 $mgkg^{-1}$, 3.20 – 4.15 $mgkg^{-1}$, and 5.38 – 7.50 $mgkg^{-1}$ for mangrove swamp, river flood plain and inland valley soils, respectively. These values were less than 15 $mgkg^{-1}$ considered suitable for all crops in the ecological zone (FMANR, 1990). The low available phosphorus could be due to the fixation of phosphorus by iron and aluminum under drained acidic condition of the soil. (Akpan- Idiok *et al;* 1996 and. Egbuchua 2007). The calcium contents of exchangeable base ranged from 4.15 – 6.40 $Cmolkg^{-1}$ in the mangrove swamp soils; 2.35 – 2.42 $Cmolkg^{-1}$ in the river flood plain and 2.01 – 2.13 $Cmolkg^{-1}$ in the inland valley soils respectively. The values on the mangrove swamp soils exceeded the critical level of 4 $Cmolkg^{-1}$. they were however low in the river flood plain and inland valley soils. The values for Mg ranged from 4.16 – 4.20 $Cmolkg^{-1}$, 0.08 – 1.05 $Cmolkg^{-1}$, and 0.05 – 0.12 $Cmolkg^{-1}$ in the mangrove swamp, river flood plain and the inland valley soils respectively. The values of magnesium in the mangrove swamp and river flood plain soils were above 0.5 $Cmolkg^{-1}$ regarded as the critical level of exchangeable Mg (FAO, 1976). The inland valley soils were low in Mg. The potassium contents ranged from 0.48 – 0.12 $Cmolkg^{-1}$ in the mangrove swamp soils exceeding the critical level of 0.2 $Cmolkg^{-1}$ established by (Unamba- Opara, 1985). On the other hand, the values were low in the river flood plain (0.03 – 0.05 $Cmolkg^{-1}$) and inland valley soils (0.05 – 0.08 $Cmolkg^{-1}$), respectively. The exchangeable Na was quite high in the mangrove swamp soils (5.01 – 5.65 $Cmolkg^{-1}$) and low in the river flood plain 0.17 – 0.18 $Cmolkg^{-1}$ and in the inland valley soils 0.17 $Cmolkg^{-1}$. The implication of high Na content in the mangrove swamp soils is the problem of salinity which means that only saline tolerable crops can survive under mangrove ecosystem. The exchange acidity was high (32.23 – 36.42 $Cmolkg^{-1}$) in the mangrove swamp soils, 8.41 – 10.45 $Cmolkg^{-1}$ in the river flood plain and 3.53 – 3.75 $Cmolkg^{-1}$ in the inland valley soils. The indirect negative fertility effect of high exchange acidity is the rise in the level of exchangeable Al + H which is a reflection of low pH of the soils (high acidity).

Fertility Capability Classification units and Interpretations

The Fertility Capability Classification and interpretations were quantitatively based on the results of the physico- chemical analysis of soils, and collaborated with those established by Sanchez and Buol (1985) for wetland soils.

Mangrove swamp soils

The fertility indicators designated as: C, O, x, h, g, w, s, and i. depict that the mangrove swamp soil have clayey (C) top soil (Types) that are characterized by low infiltration rate and very slow permeability. The O typifies Organics Soil (Peat soils) due to high accumulation of organic residues from fibrous rootlets and slow rate of litter decomposition under reduced condition.

The modifiers represented in lower case letters showed the following: (h), implying high acidity of the soil due to redox products of ferrolysis, high rainfall and its associated leaching effects. (g), depicts gleying as a major pedogenetic processes; (w) depicts ponding due to excessive waterlogging in most parts of the years, depicts salinity problem of the soils due to high electrical conductivity, and (i) which implies low phosphorus levels due to fixation processes in the soil from sesquioxides.

River flood plain / inland valley soils

The fertility indicators include; L, h, e, k, and i. These implied that the locations have loamy top soil (L) that is characterized by limiting factors of high acidity (h), low cation exchange capacity (e); low potassium reserves (k), and low contents of phosphorus (i).

In all the mapping units, the common limitations to agricultural production were wetness (w) in the forms of excessive water logging which is most pronounced in mangrove swamp soils and seasonal in the river flood plain and inland valley soils respectively. Others include high acidity (h), low phosphorus contents due to fixation processes in the soils (i), low potassium reserves (k), and salinity (s) which is most obvious in the mangrove swamp soils. Large areas of the organic soils (O) associated with mangrove swamp soil in Burutu are good for rice production.

Agricultural Potentials

The agricultural potentials of the soils showed that; The texture of mangrove swamp soils were dominantly silty clay at the surface and clayey in the sub soil horizons. The predominantly clay related texture of the soils accounts for the low permeability of the soils. (Ahn, 1993). The soils are usually waterlogged, high in acid, soluable salts and are saline in nature. These are major limitations to use. The implication is that only sensitive crops to mangrove environment such as mangrove swamp rice and raffia palms of economic values can be successfully cultivated in the soils.

The coastal inland valley and river flood plain soils have clay loamy texture which is ideal for many crop species. The soils are generally high in acidity and low in nutrient reserves such as organic matter, total nitrogen, available phosphorus and potassium. The agricultural potentials of these soils can be improved by liming, and application of both organic and inorganic manures, since their response to fertilizer application is likely to be guaranteed due to the soils characteristics.

Conclusion

The Fertility Capability Classification is a technical classification system that groups soils on the basis of soil properties that have direct influence on the soil. It is designated to detect the most important limiting factors for crop production and, group soils with similar fertility limitations and management requirements.

The soils of aquic moisture regimes in Delta State of Nigeria are characterized by such limiting factors as wetness, high acidity, low potassium reserves, low contents of phosphorus due to fixation processes, low CEC, high accumulation of soluable salts and salinity problems especially in the mangrove swamp soils. To sustainably use these soils, appropriate technology should be devised to tackle these observed abnormities. These will include effective drainage, liming, salinity control and appropriate fertilizer use based on soil test.

2: Some physical properties of soils with aquic moisture regime in Delta State, Nigeria.

Mapping Units	Depth (cm)	Sand (%)	Silt (%)	Clay (%)	Silt/clay ratios	Textural Class.
Mangrove swamps	0-25	11.6	33.4	55.4	6.03	Clay slay
	25-60	12.6	31.4	56.1	5.60	Silty clay
River flood plain	0-25	37.2	38.0	24.8	1.53	Loam
	25-60	39.2	32.0	28.8	1.11	Clay loam
Inland valleys	0-25	67.2	22.0	10.8	2.04	Sandy loam
	25-60	55-2	26.0	18.8	1.38	Sandy loam
	$\bar{X}$	37.12	30. 47	32.45	29.48	
	$\overline{Sd}$	22.30	5. 66	19.05	2 . 25	
	CV%	60. 0	18 . 6	58 . 7	7 .6	

Table 3: Some chemical properties of soils with aquic moisture regime in Delta State, Nigeria

Soil Mapping units	Depth (cm)	P^H (H_20)	pH (KCl)	E.C dsm-1	Org C (%)	Total N (%)	Avail.P. (mgkg-1)	E.A. Acidity (Cmol kg-1)	K	Ca	Na	Mg	CEC Cmol kg-1)	B.S (%)
									Exchangeable cations (Cmol kg-1)					
Mangrove swamps	0-25	5.2	6.1	15.79	7.65	2.24	5.40	36.42	6.40	4.20	0.48	5.65	28.45	58.8
	25-60	4.6	6.3	15.46	5.58	1.18	3.80	32.23	4.15	4.16	0.12	5.01	30.12	44.6
River flood plain	0-25	5.8	6.3	0.70	3.18	1.58	3.20	10.51	2.35	0.08	0.05	0.17	15.34	17.3
	25-60	6.1	6.3	0.85	2.59	0.95	4.15	8.41	2.42	1.05	0.03	0.18	18.24	20.2
Inland Valleys	0-25	5.3	6.1	0.08	2.38	1.75	7.50	3.75	2.12	0.05	0.08	0.17	17.34	14.0
	25-60	5.7	6.3	0.08	2.20	0.98	5.38	3.53	2.01	0.12	0.05	0.17	18.24	12.9
$\bar{X}$		5.45	6.21	5.49	3.93	1.45	4.91	15.80	3.24	1.61	0.14	1.89	21.29	28.0
$\overline{Sd}$		0.53	0.9	7.85	2.21	0.50	1.54	14.65	1.73	2.03	0.17	2.67	6.31	18.47
CV%		9.8	1.6	69.9	56.1	34.8	31.4	92.7	53.5	79.3	82.4	70.8	29.6	65.9

References

Ahn, P.M. (1993). Tropical Soils and Fertilizer Use. *Longman Scientific Technical, U.K*

Akpan- Idiok, A. U, Opuwaribo E.E and longanathan P. (1996). Available phosphorus status of selected soils of the Niger Delta and their relationship with iron and other soil characteristics. *Delta Agric: Vol 3: 96- 105.*

Aluko, A. P. Owunobi J. J and J. A Fagbenro (2000), Physico- Chemical properties and potentials of some wetland soil of the mangrove ecosystem for sustainable forest tree establishment. *Proceedings of the 27th annual conference of soil science society of Nigeria 5- 9th Nov. 2001.*Calabar, Nigeria.

Buol, S. W and W. Couto (1980). Soil fertility capability assessment for use in the humid tropics. In: D.J Greenland (ed). Characterization of soils in relationship for crop production . *Oxford University Press Ltd*.

Egbuchua, C. N. (2007). Pedogenetic characterization and Fertility evaluation of some wetland soils in Delta State of Nigeria. (Unpublished) Ph.D Thesis of the Delta State University Abraka, Nigeria.

Essoka, A. W. and I. Esu (2001). Physical properties of inland valley soils of Central Cross River State, Nigeria. *Proceedings of the 27th annual Conference of the Soil Science Society of Nigeria. 5- 9th Nov. 2001.*Calabar, Nigeria

FAO – Food and Agricultural Organisation of the United nations (1974). A Framework of land evaluation. *FAO soil Bulletin 32, Rome FAO.*

FAO – Food and Agricultural Organization of the United nations (1976). Agroecological zones, Vol 1. Methodology and Results for Africa. *World Resources Report. No 48 FAO, Rome.*

FMANR- Federal Ministry of Agriculture and Natural Resources (1990). Literature Review of soil fertility investigation in Nigeria. (in five Volumes).Published by the Federal Ministry of Agricultural and natural resources Lagos.

Gee, G.W. and Bauder, J.W. (1986). In Particle size analysis. Part 2 Physical and Microbiological Methods. Agron. Series No 9 ASA, Madison Wisconsin, USA.

Isirimah, N. O. (2005). Soil Fertility Capability Classes for OML 63 final report 2005. Nemconi Environment Consults services Port- Harcourt.

11TA- International Institute for Tropical Agriculture (1979). Selected methods for plant and soil analysis. *11TA manual series No 1. A.S.R J u o (ed) 70 pp.*

Mclean, E.O. (1983). Methods of soil analysis Part II America Society of Agronomy 9: 978 – 999.

Ministry of Land and Survey (2005). Geomorphological data. Vol. 3, 14 – 27. Delta State official bulletin, Asaba.

Moberg, J.P. and I. E Esu (1991). Characteristics and composition of some Savanna soils of Nigeria. *Geoderma 48: 113-129.*

Moorman, P.R and L.P Pons (1974). Characteristics of mangrove soils in relation to their agricultural land use and potentials. Proceedings of international symposium on Biological management of the mangrove. Honolulu, Hawaii 2:526-547.

Nelson, D.W. and L.E. Sommers (1982). Total carbon organic carbon and organic matter. In A.L. Page et al. (ed). Methods of soil analysis. Part 2 (2^{nd} ed.) Amer. Soc. of Agron. Madison, W.I. USA.

Obot, E.A., Oduwaiye, C.A. and Oyeleye B. (1997). Effects of mangrove swamps on species. Proceedings of the 25^{th} annual conference of Forest Assoc. of Nigeria 249 – 256.

Sanchez, P.A, W. Couto, and Buol S. W. (1982).The Fertility capability soil classification system. Interpretation, applicability and modification. *Geoderma: 27, 263- 309.*

Sachez, P.A. and Buol S.W. (1985). Agronomic taxonomy of wetland soils. In IRRI Wetland soils. Characterization, classifications and Utilization. *Proceedings of workshop Los Banos, Philippines, IRRI*: 107 – 227.

Unamba- Opara, I. (1985). The Potassium status of the sandy soils of Northern Imo State of Nigeria *Soil Science (5): 437-445*.