Potentials of Soils derived from Asu River Group and Asata Nkporo Shale for Arable Crop Production in Ebonyi State, Nigeria.

C.M. Ahukaemere*, N.S. Obasi**

**Department of Soil Science and Technology, Federal University of Technology, PMB 1526 Owerri,*
***Department of Agricultural Sciences. Imo State Poly Technique Owerri. Imo State.*
Corresponding Author: C.M. Ahukaemere, e-mail: mildredshine@yahoo.com

Abstract

Land capability classification (LCC), fertility capability classification (FCC) and land suitability evaluation of some soils of Ebonyi State were carried out for cassava, yam and maize cultivation. Land capability and fertility capability classes were obtained using the method of United State Development of Agriculture (USDA) while suitability evaluation was done using the Food and Agricultural Organization of the United Nations' (FAO) conventional method. Four (4) pedons were investigated, two from Akaeze (Asu river group) and two from Abakaliki (Asata nkporo shale) . Results of LCC showed that sites 1 and 2 (Asu river group) were classified as class II soils while sites 3 and 4 (Asata nkporo shale) were classified as class IV soils. According to FCC results, the major classes obtained were SM,g,k for site 1, A,g,k for site 2 and SA,e,k,r for sites 3 and 4 respectively. The results of land suitability evaluation showed that despite climatic factors and topography, there was no highly suitable (S1) land for maize, yam and cassava cultivation. Total nitrogen and organic carbon contents of pedons 1, 2 and 4 were marginally (S3) suitable for the production of yam and cassava while the nitrogen and organic carbon contents of pedon 3 were currently not suitable (N1) for yam and cassava cultivation. Soil texture, pH, ECEC and available phosphorus made the 4 sites moderately suitable (S2) for cassava and yam cultivation. Also, the acidic condition of the soils made all the sites moderately suitable for maize production. From the results of the aggregate suitability ratings, the major constraint for yam, cassava and maize cultivation in the sites was soil fertility (f) resulting from low organic carbon and total nitrogen contents of the soils. Though not optimum for the cultivation of the crops evaluated, the soils can still produce increased and sustainable crop yield if the appropriate husbandry practices are adopted, with particular reference to organic and nitrogen fertilizer application.

Key words: Arable crop, Fertility capability classification, Land capability classification, Land suitability evaluation.

Introduction

Nigeria is the most populous country in Africa with about 140 million citizens (NPC, 2006); approximately, 70 million are rural dwellers. Most rural residents are engaged in smallholder semi-subsistence agriculture (Ajibolade, 2005), therefore, agriculture remains a crucial sector in the Nigerian economy, being a major source of food, raw material as well as foreign exchange, employing over 70 percent of the Nigerian labor force, and serving as a potential vehicle for diversifying the Nigerian economy and enabling economic development. However, the creation of Ebonyi State in 1996, stimulated efforts to improve agriculture and rural development in Nigeria. Ebonyi State has a land mass of approximately 5,952 square kilometers (EBMOI, 2005) and a population of 2.1 million people, constituting about 1.55% of the country's population (NPC, 2006). The major occupation of the people of Ebonyi is subsistence farming with food crops dominating the practice. The agricultural type is mainly the mixed farming where food crops predominantly planted are cassava, yam, maize and rice. Generally, food crop production in Ebonyi State has been continuously practised without adequate information on land use practices. In order to avoid the drastic consequences of inappropriate land use practices, there is the need for information on the quality of land/soils in prime agricultural areas in Nigeria. The lack of comprehensive soil map indicating soil types and nutrient requirements of each crop has led to the indiscriminate application of mineral fertilizers, which poses more risk on the fragile soils (Ayeni, 2011).

Land/soil evaluation describes the characteristics of the land/soils in a given area, classifies them according to a standard system of classification, plots boundaries of the land/soils on a map and make predictions about the behaviour of the land/soils (USDA, 1993). The information helps in the development of land use plans, evaluates and predicts the effects of land use on the environment (Shepande,2002). The objectives of most soil survey investigations are to provide data for the rational planning and adjustment of land use (Hubrechts et al., 2004). Optimum crop production can be achieved through the rational use of fertilizers accompanied with other management practices that take cognizance of the variability of the soils (Omotosho and Akinbola, 2007). The shortage of prime land in some cases have led to land use and environmental conflicts. The knowledge of the pattern of land/soil distribution and the characteristics of each unit of land/soil are very essential for a better understanding, use and management of soils/lands (Nuga and Akinbola, 2011). In the face of these disturbing realities, the major objective of this study was to evaluate the potentials of soils of Akaeze and Abakaliki in Ebonyi state for the cultivation of maize, yam and cassava.

Materials and Methods

Description of the Study Area

The study was carried out at two (2) different locations namely, Afikpo North and Akaeze (Latitudes 5° 30^1, 5° 9^{1}N and Longitudes 5° 5^1, 7°.6^1 E) in Ebonyi State, South-east Nigeria. The lithological materials from which the soils of the areas were developed are Asata nkporo shale (Afikpo) and Asu River group (Akaeze). Generally, Ebonyi State falls within the tropical rainforest zone of South-east Nigeria with a humid tropical rainfall range of 1500 mm to 2500 mm. The average annual atmospheric temperature ranged from 26°C to 30°C (NIMET, 2014). It has a land mass of approximately 5,952 square kilometers (EBMOI, 2005) and a population of 2.1 million people (NPC, 2006). The major occupation of the people of Ebonyi is subsistence farming with food crops dominating the practice. The agricultural type is mainly the mixed farming where food crops predominantly planted are maize, cassava, yam and rice.

Soil Sampling and Laboratory Analysis

Reconnaissance field trip was undertaken and routine materials and methods to be used in the field study were noted. With the aid of a geological map of the area, the two sampling areas (Akaeze and Abakaliki) were selected randomly. Four (4) pedons were dug (two in each site), described and sampled according to the procedure of FAO, (2006) and Soil Survey Staff, (2006). Samples were collected based on horizon differentiation from the pedons.. Three representative soil samples were collected from each of the various identified genetic horizons of the soil profiles for laboratory analyses. The soil samples were air-dried, crushed and made to pass through 2.0 mm mesh sieve. Samples were also collected with core samplers for bulk density analysis. Particle size analysis was performed using the Bouyoucous hydrometer method (Gee and Or, 2002). Bulk density was determined using the core method as described by (Gross and Reinsch 2002). Exchangeable base cations (Ca, Mg, K, and Na) were extracted with 1 N NH4OAc (pH 7) (Thomas, 1996). Exchangeable calcium and magnesium were determined by EDTA complexio-metric titration while exchangeable potassium and sodium were determined by flame photometry. Effective Cation Exchange Capacity (ECEC) was calculated by the summation of the total exchangeable bases and total exchangeable acidity. Soil organic carbon was analyzed by Walkley and Black wet digestion method (Nelson and Sommers, 1982) while total nitrogen was determined by the method of Bremner and Mulvaney (1982). Available phosphorus was determined by Bray-II method (Olsen and Sommers 1982). Soil pH was measured potentiometrically in water at the soil-liquid ratio of 1:2.5 (Thomas, 1996).

Land Evaluation and Data Analysis

Means of the data generated from soil laboratory analyses were calculated. FCC was done according to USDA fertility capability classification system modified by Sanchez et al., (2003) while LCC was done according to USDA Land Capability Classification System (Klingebiel and Montgomery, 1961). Land suitability evaluation was carried out using the FAO (1976); modified by Sys, (1985; 1991) guidelines for land evaluation. Key environmental factors considered in the evaluation were climate (annual rainfall and temperature), topography (slope) and soils. The criteria employed for the evaluation of soils were soil depth, soil texture, drainage, pH, available P, organic carbon, total N, effective CEC, and base saturation. The identified soil units were placed in suitability classes by matching their characteristics with the requirements of the test crops. The most limiting characteristic dictated overall suitability for each soil. The suitability of each factor for each soil unit was classified as highly suitable (S1), moderately suitable (S2), marginally suitable (S3) and currently not suitable (N1).

Results and Discussion

Physical and Chemical Properties of Soils

Considering the two soil groups investigated, the average sand content ranged from 34.40 -35.40% (Asu river group) and 75.4 -76.00% (Asata nkporo shale). The four pedons had mean silt content range of 39.20 and 40.60% with 39.20, 40.60, 7.20 and 6.00% for pedons 1, 2, 3 and 4 respectively (Table 1).

Table 1. *Land/Soil Characteristics of the Sites.*

Land characteristics	Pedon 1	Pedon 2	Pedon 3	Pedon 4
Climate (c)				
Annual rainfall (mm)	1700-2250	1700-2250	1700-2250	1700-2250
Relative humidity (%)	70 – 85	70 – 85	70 – 85	
Temperature (^{o}C)	24-30	24-30	24 -30	
Topography (t)				
Slope (%)	0-1	0-1	4	4.5
Soil physical characteristics				
Wetness (w)				
Drainage	2-3	2-3	1	1
Bulk density (g/cm^3)	1.49	1.45	1.42	1.25
Sand (%)	35.40	34.40	75.40	76.00
Silt (%)	39.20	40.60	72.00	60.00
Clay (%)	25.36	24.94	17.36	17.36
Texture	SCL	SL	SL	SL
Soil depth (cm)	122	128	137	115
Soil fertility (f)				
Ca (cmol$_{+/}$kg)	5.06	3.34	0.96	0.74
Mg (cmol$_{+/}$kg)	3.12	3.36	1.37	1.04
K (cmol$_{+/}$kg)	0.03	0.01	0.006	0.005
Na (cmol$_{+/}$kg)	0.01	0.01	0.01	0.01
ECEC (cmol$_{+/}$kg)	12.98	12.87	3.41	11.51
BS (%)	65	52	67	44
Organic carbon (g/kg)	6.85	6.74	3.99	4.71
pH	5.91	5.97	5.67	5.70
Total nitrogen (g/kg)	0.65	0.66	0.41	0.51
Av. Phosphorus (mg/kg)	10.12	8.92	8.34	20.74

Drainage: 1 = Well drained, 2 = Moderately drained, 3 = Imperfectly drained, 4 = poorly drained, 5 = very poorly drained, SCL = Sandy clay loam, SL = Sandy loam

The average clay content ranged between 17.36 and 25.36%; with pedon 1 having a mean value of 25.36%, whereas pits 2, 3 and 4 had mean values of 24.96, 17.36, and 17.36% respectively (Table 1). The textural class of the soils of the Asu river formation comprised generally of sandy clay loam, loam and sandy loam while the textural class of the soils of the Asata nkporo shale comprised of sand, sandy loam and loamy sand. However, the sand, silt and clay fractions of the soils and their textural class generally represent soils of the area as was shown by previous studies (Ande *et al*., 2016; Tijani *et al*., 1996). Results showed that mean bulk density values ranged from 1.49 - 1.45 g/cm^3 in pedons underlain by Asu river group and 1.42 -1.25 g/cm^3 in pedons underlain by Asata nkporo shale. The mean bulk density values of the two soil groups fall within the range that is expected of tropical soils.

Table 2. *Land Capability Classification (LCC) of Soils.*

Soil group	Class	Limitations
Asu river group		
Pedon 1	Class II,w	Wetness
Pedon 2	Class II,w	Wetness
Asata nkporo shale		
Pedon 3	Class IV,r,s	Rock outcrop, slope
Pedon 4	Class IV,r,d,s	Rock outcrop, depth, slope

w = wetness, r = rock outcrop, d = shallow depth, s = slope

The pH data showed that soils were moderately acidic in water with mean pH values ranging from 5.92 and 5.97 in soils derived from Asu river group; 5.67 and 5.70 in those derived from Asata nkporo shale respectively. Onwudike *et al*. (2016) and Olabode, O.S (1997) reported similar pH values in some soils of Nigeria. Abua *et al*. (2010); attributed soil pH of an area to the nature of the parent material, climate of the region, organic matter and topographic situations. The acidic nature of the soils investigated could be attributed to the high rainfall resulting in the leaching of some base-forming cations especially from the surface horizons of the soils. Organic carbon content of the soils was generally low. Highest organic carbon values (6.85 and 6.74 g/kg) were recorded in profiles 1 and 2 of Asu river group. On the other hand, organic carbon content of soils of the Asata nkporo shale ranged from 4.712-3.99 g/kg. Average total nitrogen (TN) content of the soils was very low (< 0.66 g/kg) in all the pedons investigated. The low nitrogen concentration is a common phenomenon in the soils of Southeastern Nigeria and is as a result of the high nitrogen losses sustained in these soils through the leaching of nitrates, as well as the rapid mineralization of organic matter under the isohyperthermic soil temperature regime (Ahukaemere, 2015). The available phosphorus content of the soils of the Asata nkporo shale (20.75 – 8.34 mg/kg) was relatively higher than those of the Asu river group (10.12 – 8.92 mg/kg). However, the available phosphorus concentration in soils of the Asu river group was moderate while that of Asata nkporo shale was rated medium to high since (Beerneart and Bitondo, 1992) reported the critical P values as < 5, 5-15 and >15 mg/kg for low, medium and high respectively.

Exchangeable calcium values ranged from 3.34 – 5.06 cmol+/kg in soils of the Asu river group and 0.96 – 0.74 cmol+/kg in soils of the Asata nkporo shale. However, soils of Asata nkporo shale were acutely deficient in calcium compared to those of Asu river group indicating less leaching losses in these soils. Exchangeable magnesium was higher than the critical value of 1.2 cmol+/kg (Esu, 1999) in all the soils. The low calcium concentration in soils of the Asata nkporo shale can be attributed to the acidic nature of the parent rocks, coupled with the influence of the leached profile under high annual rainfall condition of the region (Eshett *et al.*, 1988). Exchangeable potassium concentration was extremely low (< 0.3 cmol+/kg). Idigbor *et al.* (2008) attributed the low potassium concentration in the soils of South-eastern Nigeria to the fact that there is generally a low potassium reserve in acid soils. This could be attributed to the highly mobile nature of exchangeable potassium relative to calcium and magnesium and its consequent massive loss through leaching (Thompson, 1957).

Table 3. *Fertility Capability Classification (FCC) of soils.*

Soil group	Fertility class/limitations
Asu river group	
Pedon 1	SM,g,k
Pedon 2	A,g,k
Asata nkporo shale	
Pedon 3	SA,e,k,r
Pedon 4	SA,e,k,r

S = sandy top soils, M = Fine loamy subsoil, A = Coarse loamy topsoil and subsoil, g = gley, k = Potassium deficiency, e = low CEC (ECEC), r= rock or root restricting layer.

Land Capability Classification of the Sites

The Land Capability Classification (LCC) of the two investigated soil groups are shown in Table 2. Soils derived from the Asu river group as shown in profile pits 1 and 2 were classified as class II soils according to USDA Land Capability Classification System (Klingebiel and Montgomery, 1961). The soils of Asu river group have some limitations that reduce the choice of crops or require moderate conservation practices. Generally, the limitations of soils in this class include the effect of gentle slopes, moderate susceptibility to erosion, less than ideal soil depth, somewhat unfavourable soil structure, occasional damaging overflow, wetness correctable by drainage. These soils require more than ordinary management practices for obtaining optimal production and for maintaining productivity. However, Obasi *et al*., (2014) noted that farmers in these regions have subjected large area of this soil group into lowland rice farming, while the adjacent uplands are used for cassava, maize and yam production.

Table 4. *Land Requirements for Cassava.*

	Factor suitability rating			
Land Qualities /characteristics	Highly suitable (S1)	Moderately suitable (S2)	Marginally suitable (S3)	Not suitable (N)
Climate (c)				
Annual rainfall (mm)	1100-1500	900-1100	500-900	<500
Temperature (^{o}C)	18-30	12-18	<12	Any
Soil physical characteristics (s)				
Soil depth (cm)	>100	100-75	50-75	< 50
Soil texture	L, SC, CL	LS, SiCL, SL	Sand, SiC	Clay
Topography (t)				
Slope (%)	0-5	5-12	12-20	>20
Wetness (W)				
Drainage	1	2-3	4	5
Soil Fertility Status (f)				
pH	6.1-7.3	5.1- 6.0 or 7.4-7.8	<4.0 or >8	Any
Total N (g/kg)	> 2.0	1.0-2.0	<1.0	Any
Av. P (mg/kg)	>25	6-25	<6	Any
Organic C.(g/kg)	>20	15-20	8-15	<8
Ex. K ($cmol_{+/}$kg)	>6	3-6	<3	Any
ECEC ($cmol_{+/}$kg)	>16	3-16	<3	Any
Base saturation (%)	>35	20-35	<20	Any

Source: Source: Sys *et al.* (1991).
Drainage: 1 = Well drained, 2 = Moderately drained, 3 = Imperfectly drained, 4 = poorly drained, 5 = very poorly drained, L = loam, CL = clay loam, SC = sandy clay, SiC = Silty clay, LS = loamy sand

Land Capability Classification of soils of Asata Nkporo Shale group reveals a Class IV soils (Klingebiel and Montgomery, 1961), as shown in profile pits (sites) 3 and 4 (Table 2). Class IV soils have very severe limitations that restrict the choice of plants and or require very careful management practices. Restrictions, both in terms of choice of crops and or management and conservation practices are greater in Class IV to such an extent that production is often marginal in relation to the inputs required. Limiting factors are of the same nature as in the previous classes but more severe and difficult to overcome. Several limitations such as steep slopes, shallow depth, rock outcrops are permanent features of the sites. Some of the limitations due to sloppiness and erosion hazards in classes II to IV can be reduced by biological terracing as practised in agroforestry and alley cropping. However, in the USDA LCC system, soils of classes II-IV are moderately suitable for cultivation with minor to moderately severe limitations and require management practices while soils of classes V to VIII are generally not suitable for cultivation, although certain of them may be made suitable for agricultural use with costly measures.

Fertility Capability Classification of the Sites

The fertility capability classes of the investigated soils are shown in Table 2. Asu river group site 1 (pedon 1) had a sandy topsoil (Type) and sandy clay loam subsoil (Subtrata Type) in their textural composition. Asu river group site 2 (pedon 2) had sandy loam as both topsoil and subsoil texture within the 50 cm depth. The major limiting factor of soils of Asu river group was drainage as the sites experience saturation with water for 60 or more consecutive days in most years. Also, there is K deficiency as exchangeable K was < 2% of the summation of bases. The summation of bases, 8.23 cmol+/kg of soil (site1) and 6.72 cmol+/kg of soil (site 2) were very low when compared to100 cmol+/kg acceptable limits (Sanchez *et al*.., 2003). The Fertility Capability classification (FCC) of Asata nkporo shale group as shown in Table 3 indicated that sites 3 and 4 had a sandy topsoils (S) and coarse loamy subsoil (A). The limitations of soils of this group include very low CEC (e) 3.41cmol+/kg (site 3) and 4.06 cmol+/kg (site 4) as Sanchez *et al*.., (2003) acceptable limits of CEC is 40 cmol+/kg. The soils of Asata nkporo group also showed the presence of rocks (r) which may cause root restriction within the 50 cm depth. Quang, (2011) suggested that the use of mineral fertilizers is not recommended in these soils in their natural state, as nutrients are not retained by soils with low CEC (e) due to the low capacity to retain nutrients. In addition, leaching causes big nutrient losses when lime and fertilizers are applied; therefore, heavy applications of these nutrients and of N fertilizers should be split. Organic matter application is also recommended to increase soil cation exchange capacity. Low Nutrient Capital Reserves (k), Potassium fertilizers must be added. Generally, these soils have also the limited capacity to retain nutrients and the potassium, calcium and magnesium added can be easily lost (Nguyen, 2003).

Suitability Classification of the Soils for Cassava and Yam Production

Tables 4 and 5 showed the land requirement for cassava and yam as described by Sys et al. (1985 and 1991). When land requirements of the test crops were matched with the land quality of the studied sites (Table 1), all the soils were highly suitable in terms of climatic and slope requirements for yam and cassava production (Table 7).

Table 5. *Land Requirements for Yam.*

	Factor suitability rating			
Land Qualities /characteristics	Highly suitable (S1)	Moderately suitable (S2)	Marginally suitable (S3)	Currently not suitable (N1)
Climate (c)				
Annual rainfall (mm)	>800	800-500	<500	Any
Temperature (^oC)	18-29	15-18	12-15	<12
Relative humidity (%)	>75	75-65	<65	
Soil physical characteristics (s)				
Soil depth (cm)	Deep (>75)	60-75	40-60	< 40
Soil texture	LS	SL, SCL	Sand, SiC, CL	Clay
Topography (t)				
Slope (%)	< 4	4-8	>8	>20
Wetness (W)				
Drainage	1	2-3	4	5
Soil Fertility Status (f)				
pH	6.1-7.3	5.1- 6.0 or 7.4-7.8	<4.0 or >8	Any
Total N (%)	> 1.5	1.0-1.5	1.0-0.5	<0.5
Av. P (mg/kg)	>25	6-25	<6	Any
Organic C (%)	>20	15-20	8-15	<8.0
Ex. K ($cmol_{+/}kg$)	>6	3-6	<3	Any
ECEC ($cmol_{+/}kg$)	>16	10-16	3-10	<3
Base saturation (%)	>35	20-35	<20	Any

Source: Sys *et al* (1991), Drainage: 1 = Well drained, 2 = Moderately drained, 3 = Imperfectly drained, 4 = poorly drained, 5 = very poorly drained, CL = clay loam, SL = sandy loam, SiC = Silty clay, LS = loamy sand

These results indicated that the study area is currently ideal in terms of climate for the cultivation of both crops. Some works done in south-east Nigeria showed that the climatic condition of the area is ideal for the production of most arable crops (Ahukaemere *et al*., 2015; Ajiboye and Olaniyan, (2016); Udoh *et al*., 2011; Nuga and Akinbola, 2015). Similarly, the depth and base saturation of the soils made the sites highly suitable (S1) for the cultivation of both crops.

Table 6. *Land requirements for Maize.*

	Factor suitability rating			
Land Qualities/characteristics	Highly suitable (S1)	Moderately suitable (S2)	Marginally suitable (S3)	Currently not suitable (N1)
Climate (c)				
Rainfall (mm)	>800	700-800	600-700	<600
Temperature (^{o}C)	24-30	20-24	15-20	<15
Soil physical characteristics (s)				
Soil depth (cm)	>120	75-120	30-75	< 30
Soil texture	CL,L	SL, LS	LCS	CS
Topography (t)				
Slope (%)	0-2	4-8	8-16	>16
Drainage	Well drained	Moderately drained	Imperfectly drained	Poor
Soil fertility status (f)				
pH	6.0-6.5	5.5-6.0	5.0-5.5	< 5.0
Total N (g/kg)	>1.5	1.0-1.5	0.5-1.0	< 0.5
Available P (mg/kg)	>40	10-40	3-10	< 3
CEC (cmo1$_{+}$/kg)	>25	13-25	6-13	< 6
Organic C (g/kg)	>20	10-20	5-10	< 5
Base saturation (%)	>80	40-80	20-40	< 20

Source. (FAO, 1976).
CL = Clay loam, L = Loam, SL = sandy loam, LS = Loamy sand, LCS = Loamy coarse sand, CS = Coarse sand.

When the texture, pH, effective cation exchange capacity (ECEC) and available phosphorus requirements of yam and cassava were matched with land characteristics of the sites, they were moderately suitable (S2) for the production of both crops.

Table 7. *Suitability Assessment of the Sites for Yam, Cassava and maize.*

	Yam				Cassava				Maize			
Land characteristics/ qualities	Pedon 1	Pedon 2	Pedon 3	Pedon 4	Pedon 1	Pedon 2	Pedon 3	Pedon 4	Pedon 1	Pedon 2	Pedon 3	Pedon 4
Climate (c)												
Annual Rainfall (mm)	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1
Relative. humidity (%)	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1
Temp. (^oC)	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1
Topography (t)												
Slope (%)	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S2	S2
Wetness (w)												
Drainage	S2	S2	S1	S1	S2	S2	S1	S1	S2	S2	S1	S1
Soil physical characteristic (S)												
Texture	S2	S2	S2	S2	S2	S2	S2	S2	S1	S2	S2	S2
Soil depth (cm)	S1	S1	S1	S1	S1	S1	S1	S1	S2	S1	S1	S2
Soil fertility (f)												
pH	S2	S2	S2	S2	S2	S2	S2	S2	S2	S2	S2	S2
OC (g/kg)	S3	S3	N1	S3	S3	S3	N1	S3	S3	S3	N1	N1
Av. P (g/kg)	S2	S2	S2	S2	S2	S2	S2	S2	S2	S3	S3	S2
TN (g/kg)	S3	S3	N1	S3	S3	S3	S3	S3	S3	S3	N1	S3
ECEC	S2	S2	S2	S2	S2	S2	S2	S2	S3	S3	N1	S3
BS (%)	S1	S1	S1	S1	S1	S1	S1	S1	S2	S2	S2	S2
Aggregate suitability	S3 (f)	S3 (f)	N1(f)	S3(f)	S3(f)	S3(f)	S3(f)	S3(f)	S3 (f)	S3 (f)	N1(f)	N1(f)

Total nitrogen of all the soils was marginally (S3) suitable with exception of pedon 3 where the nitrogen content is currently not suitable for yam and cassava cultivation. Furthermore, organic carbon made soils of pedon 3 not suitable (N1) while other pedons were marginally suitable for yam and cassava cultivation. Generally, soil fertility (low organic carbon and total nitrogen contents) was a serious constraint to both yam and cassava cultivation in the sites investigated.

Suitability Classification of the Soils for Maize Production

Table 6 showed the land requirement for maize as described by FAO, (1976); Sys et al. (1985). When land requirements of maize were matched with the land quality of the studied soils (Table 1), all the sites were highly suitable (S1) in terms of the climatic requirements for maize production. The topography of sites 1and 2 was favourable while that of sites 3 and 4 was moderately suitable for maize cultivation. Soil drainage made pedons 1 and 2 moderately suitable (S2) and pedons 3 and 4 highly suitable (S1) for maize production. Also, pedon 1 was highly suitable while others were moderately suitable when soil texture of the sites was matched with the soil texture requirement of maize. However, considering the depth of the pedons, pedons 1 and 4 were moderately suitable while pedons 2 and 3 were highly suitable (S1) for maize production (Table 7). The acidic condition of the soils made all the sites moderately suitable for maize production. Currently, considering the organic carbon contents of the soils, sites 1 and 2 are marginally suitable (S3) while sites 3 and 4 are not suitable (N1) for the production of maize. Considering the total nitrogen contents of the different sites investigated, pedon 4 was not suitable while pedons 1, 2 and 3 were marginally suitable for maize cultivation. The phosphorus contents of the sites made site 1 and 4 moderately suitable (S2) and site 2 and 3 marginally suitable for maize production.

Aggregate Suitability Evaluation of Studied Sites

The results of the aggregate suitability ratings showed that sites 1, 2 and 4 are currently marginally (S3) suitable for both yam and cassava cultivation while pedon 3 is not suitable (N1) for yam cultivation. The major land characteristic limiting the cultivation of these crops was soil fertility, which resulted from low organic carbon and total nitrogen contents of the soils (Table 7). For maize, sites 1 and 2 are currently marginal suitable (S3f) while sites 3 and 4 are currently not suitable (N1f) for the cultivation of maize. Generally, the major limitation for the optimum production of cassava, yam and maize in all the sites was soil fertility.

Conclusions

The climatic condition of the sites investigated made the sites highly suitable for yam, cassava and maize production. However, organic carbon and total nitrogen made the sites currently not suitable (N1) for yam, cassava and maize production. For optimum performance of the test crops, proper agronomic practices should be carried out to improve the fertility status of the soils. Organic matter application is also recommended to increase soil cation exchange capacity. As nutrient deficiency and low organic carbon content are the most important limiting factors, it needs to be alleviated so as to sustain crop production in the soils studied. Also, leaching causes big nutrient losses when lime and fertilizers are applied; therefore, heavy applications of these nutrients and of N fertilizers should be split. Organic matter application is also recommended to increase soil cation exchange capacity.

References

Abua, M. A., R, A.,Offiong, A. I. Iwara, U. W. Ibor, 2010. Impact of Newly Constructed Roads on Adjoining Soil Properties in Tinapa Resort, South-Eastern Nigeria**.** *Annals of Humanities and Development Studies,* 1(1):176-184.

Ahukaemere, C.M., 2015. Sequestration and Dynamics of Carbon and Nitrogen in Soils of Dissimilar Lithologies under Different Land Use Types in South-east Nigeria. A Ph.D Thesis of Department of Soil Science and Technology, Federal University of Technology, Owerri Nigeria. 266 pp.

Ahukaemere, C.M., I.I. Ekpe, C.I. Unachukwu, 2015. Suitability Evaluation of Soils Derived from Dissimilar Lithological Materials for Maize and Groundnut Production in Owerri Agricultural Zone, Southeastern Nigeria. Malaysian Journal of Soil Science, Vol. 19. 73-82.

Ajibolade, E. O., 2005. Effects of Land Acquisition for Large Scale Farming On the Productivity Of Small Scale Farming In Okitipupa, LGA, Ondo State. Master's Thesis, Department of Agricultural Economics And Extension, FUTA, Akure.150 pp.

Ajiboye, G.A and J.O. Olaniyan, 2016. Characteristics and suitability evaluation of the white soils of Etung LGA for oil palm and plantain production. Agrosearch 16 (2), 25-40.

Ande, O.T., O.A. Ojo, O.D. Adeyolanu, S.K. Are, A., Adelana, A. Oke, A.A. Adetayo, G. Oluwatosin, 2015. Digital soil mapping and morphogenetic characterization of soils of Ebonyi formation in south eastern Nigeria. Earth science research vol.5 (1).

Ayeni, L.S., 2011. Integrated plant nutrition management : A panacea for sustainable crop production in Nigeria. International Journal of Soil Science 6(1): 19-24.

Beernaert, F., D. Bitondo, 1992. A Simple and Practical Method to Evaluate Analytical Data of Soil Profiles. CUDs, Soil Science Department. Belgian Cooperation Dschang Cameroon. 65 p.

Bremner, J. M G. S. Mulvaney, 1982. Nitrogen total. *In*: A. L. Page, R. H. Miller and D. R. Keeney, (eds.) Methods of soil analysis. Parts 2. American Society of Agronomy, No, 9, Madison, WIS Pp. 595-624.

Ebonyi State Ministry of Information (EBMOI), 2005. Ebonyi State Ministry of Information Diary. A Publication of the Ministry of Information, Abakaliki, Ebonyi State.

Eshett, E.T., J.A.I Omoeti,. A.S.R. Juo, 1988 Characterization of wetland soils supporting rice production in Southeastern Nigeria. *Thailand Journal of Agricultural Science* 21: 31-50.

FAO. 1976. *A Framework for Land Evaluation.* FAO Soils Bulletin No. 32. FAO, Rome, Italy: Soils Resources Development and Conservation Services, Land and Water Development Division.

FAO 2006 Guidelines for soil description (4th ed.). Rome: Food and Agriculture Organization of the United Nations. 97 pp.

Gee, G.W., D. Or, 2002. Particle size distribution: In Dane J.H., Topp G.C. (eds). Methods of soil analysis Part 4 Physical methods. Soil Sci. Soc. Am Book series No. 5 ASA and SSSA, Madison WI; 225-293

Grossman, R.B, T.G Reinch 2002. Bulk density and linear extensibility In: Methods of soil analysis part 4. Physical methods Dane, J.H and G.C.Topp(eds). Soil Science soc. Am.Book series no. 5 ASA and SSA madison, W.I, Pp : 201- 228.

Hubrechts, L., K. Vander Poorten, M. Vanclosster, J. Deckers, 2004. From Soil Survey to quantitative land evaluation in Belgium. European Soil Bureau Research Report No 4. www.nlfb.de/bode/downlonds/proceed/32.pdf Retrieved 15/5/04.

Idigbor, C.M., D.O. Asawalam, O.O. Agbede, 2008. Phosphorus forms and P sorption Capacity of Fauna Modified Soils of South-Eastern Nigeria. Journal of Agricultural Production and Technology. 4 (2): 195-210.

Klingebiel, A.A., P.H. Montgomery, 1961. Land capability classification. Agriculture handbook no 210. Soil conservation service, Washington D.C. US Department of Agriculture (USDA).

National population commission (NPC), 2006. Population and Housing Census, Population Distribution by Sex, State, LGA and Senatorial District.

Nelson, D. W. and Sommers, L. E. (1982) Total carbon, organic carbon and organic matter. *In:* A. L. Page, R. H. Miller and D. R. Keeney (eds.) Methods of soil analysis (Part 2). American Society of Agronomy. Madison, WIS. Pp. 539-599.

Nguyễn, M. H., 2003. Soil potassium dynamics under intensive rice cropping. A case study in the Mekong Delta, Vietnam. Ph.D thesis Wageningen University, Netherlands.

NIMET (Nigerian Meteorological Agency), Nigeria, 2014. Climate Weather and Water Information, for sustainable development and safety. Annual Climatic Report.

Nuga, B.O., G.E. Akinbola 2011. Characteristics and classification of soils developed over coastal plain sand and shale parent material in Abia state Nigeria. Journal of Technology and Education in Nigeria (JOTEN), Vol. 16, No. 1, 36.

Nuga, B.O., G.E. Akinbola, 2015. Land suitability evaluation of soils on two mapping units for some arable crops in south eastern Nigeria. Journal of Agricultural and Veterinary Sciences. Vol. 8, Issue 3. Ver. 111. 66-77.

Obasi, S.N., C. C. Obasi, S.G.I. Ikeh, C.B. Nwaiche, C.N. Chukwukere, 2014. Suitability Evaluations of Selected Rice Soils of Southern Ebonyi State, Southeastern Nigeria. Proceedings of the 48th Annual Conference of Agricultural Society of Nigeria, Abuja. Pp 1163-1170.

Olabode, S.O, 1997. Comparsion of the physical and chemical properties of soils under natural forest and Gmelina plantation. Agrosearch Journal, Vol. 3 (1 and 2): 19-30

Olsen, S., R. Somers, 1982 Phosphorus. *In:* A. L. Page, R. H. Miller and D. R. Keeney (eds.) Methods L.E. of soil analysis (Part 2). American Society of Agronomy, Madison WIS, Pp 403-430.

Omotosho, S.O. and G. E. Akinbola, 2007. Variability of soil properties at the transition zone between two parent materials in south western Nigeria.. International Journal of Soil Science 2(3): 218-223.

S.U. Onwudike, B.U. Uzoho, E.E. Ihem, C.M. Ahukaemere, U. Nkwopara, I.F. Irokwe, G.I. Echeanyanwu, 2016, Evaluation of the fertility status of selected soils in Mbaise Imo state Southeastern Nigeria using nutrient index method. Agrosearch 16 No. 1: 79 – 90.

Quang V.M., 2011. The rice soil fertility capability classification system. International journal of environmental and rural development.

Sanchez, P.A., C.A. Palm, S.W. Buol, 2003. Fertility capability soil classification: a tool to help assess soil quality in the tropics. Geoderma 114, 157-182.

Shepande, C., 2002. Soils and land use with particular attention and land evaluation for selected land use types in the Lake Naivasha Basin. Kenya. Unpublish. M.S.C. Thesis in Soil information, ITC. Enschede Netherlands.

Soil Survey Staff, 2006. Keys to soil taxonomy (9th ed.). Washington, DC: Natural Resources Conservation Service, United States Department of Agriculture (USDA). 332pp.

Sys, C., 1985. Land evaluation. Publication No. 7 of the General Administration of Cooperative Development, Part 1-111 247p. Place de champs de mars 5, Biote 57, 1050 Bruxelles.

Sys, C., 1991. Land evaluation and crop production. Agricultural publication. No.7. General Admin for Development Corporation, Brosels: 247.

Thomas, G.W., 1996. Soil pH and Soil Acidity. In: Methods of Soil Analysis, Part 3 chemical Methods. L.D. Sparks (ed.). SSSA Book Series. No 5.

Thompson, L.M. (1957) Soils and soil fertility (2^{nd} ed.). New York: McGraw Hill Book Company Inc. Pp. 270.

Tijani, M. N, E.P, Loehnert K.O. Uma, 1996. Origin of saline ground waters in Ogoja area, lower Benue Trough, Nigeria. J. Afr. Earth Sci., 23(2): 237-252.

Udoh, B.T., H.B. Henry, U.S. Akpan. 2011. Suitability evaluation of alluvial soils for rice and cocoa cultivation in acid sands Area of southeastern Nigeria. Journal of Innovation Research in Engineering and Science **2(3):** 148-161.

USDA 1993. Soil Survey manual. USDA Hand book. 18 US. Gov. Print Office, Washington, D.C. Walkley, A. and I. A. Black. 1934. An Examination of Degtjareff Method for Determining Soil Organic Matter and a Proposed Modification of the Chromic Acid Titration Method. Soil Sci. 37:29-37.