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Suitability Evaluation of Soils Derived from Dissimilar Lithological Materials for Maize and Groundnut Production in Owerri Agricultural Zone, Southeastern Nigeria

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ABSTRACT

Suitability evaluation of soils derived from three different parent materials in the Owerri agricultural zone for maize and groundnut cultivation was done using the Food and Agricultural Organization of the United Nations' (FAO) conventional method. Data were obtained from six pedons, two from each parent material. The results showed that despite climatic factors, soil depth, topography, and base saturation, there was no one highly suitable (S1) land for maize and groundnut cultivation. The organic carbon contents of the soils derived from Imo clay shale were highly suitable (S1) for groundnut cultivation. Soils derived from alluvium and coastal plain sands were only moderately suitable (S2) for groundnut cultivation. Generally, the soils derived from the three different parent materials were moderately suitable (S2) for maize production when their carbon contents matched the organic carbon requirement of the crop. In view of the aggregate suitability ratings, the major constraint for both groundnut and maize cultivation in the soils was soil fertility (f). Though not currently suitable (N) for groundnut and maize cultivation, the soils can still produce increased and sustainable crop yield if the appropriate husbandry practices are adopted, with particular reference to phosphate fertilizer application.

Keywords: Soil parent materials, maize, groundnut, land suitable evaluation, FAO conventional method

INTRODUCTION

Different parent materials affect the mineralogy, chemistry and morphology of soils under the same conditions such as topography and vegetation, especially in the tropics. Differences in physical, chemical and mineralogical properties of soils are related primarily to parent material (Irmak *et al*., 2007). According to Gray and Murphy (2002), parent material is a major source of most nutrients necessary for plant growth, with the notable exceptions being oxygen, hydrogen, nitrogen and carbon which are primarily derived from the atmosphere and organic material. The productivity of soil and its ability to retain nutrients as indicated by its cation exchange capacity (CEC) are influenced by parent material. Despite these

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observations, the suitability of soils, under different land use and management practices for crop production in Nigeria, has been over emphasized over the years. However, a good understanding of the suitability of soils derived from varying parent materials for the cultivation and sustainability of major staple and cash crops (especially maize and groundnut) in Nigeria is limited.

Land evaluation is the process of estimating the potential of a piece of land for alternative uses (FAO, 1983). Land evaluation tells the farmer the suitability or limitations of his/her land for specific uses. This is achieved by matching land qualities/characteristics with the requirements of the envisaged land use (Udoh *et al*., 2011). The result of land evaluation should reflect not only possible yield, but more importantly, the ease or difficulty of ensuring the sustained use of the parcel of landfor a particular purpose (Baja, 2009).

Globally, maize (*Zea mays*) and groundnut (*Arachishypogea*) are crops of economic importance. Groundnut is a major internationally traded cash crop and supports the economy of the producing countries,besides providing gainful employment for many people. Maize, on the other hand, is a stable food of about 50% of the world's population (IITA, 2013). In order to achieve success in large-scale production of these crops by governments and individuals, more lands must be cultivated. However, there is paucity of information on the extent to which the land qualities of soils derived from coastal plain sands, alluvium and Imo clay shale can satisfy the agronomic requirements of maize and groundnut. Therefore, this study aimed to evaluate the suitability and limitations of these soils for optimum and sustainable productivity of groundnuts and maize.

MATERIALS AND METHODS

Description of the Study Areas

The study was conducted at Umuna in Okigwe (latitude 5^{o}46N and longitude 7^{o}15 E), Oguta in Oguta LGA (latitude 5^{o}39N and longitude 6^{o}45E) and Ihiagwa in Owerri (latitude 5^{o}2 N and 7^{o}04 E), all in Imo State. Umuna, Oguta and Ihiagwa soils are derived from Imo clay shale (Imo shale group), alluvium deposits and coastal plain sands, respectively (*Figure 1*). The climate is humid and tropical, with an average annual rainfall of 2500 mm, a mean annual temperature varying between 27 and 28^{o}C, and relative humidity of between 75 and 80% (NIMET, 2008).

Field Work

Three different parent materials (alluvium, Imo clay shale and coastal plain sands) were randomly selected for the study. A total of six soil profile pits were dug, two for each parent material. These soil profile pits were dug and described according to FAO's (2006) guidelines, and samples were collected according to genetic horizons. Five representative soil samples were collected from each of the various identified genetic horizons of the soil profiles for laboratory analyses.

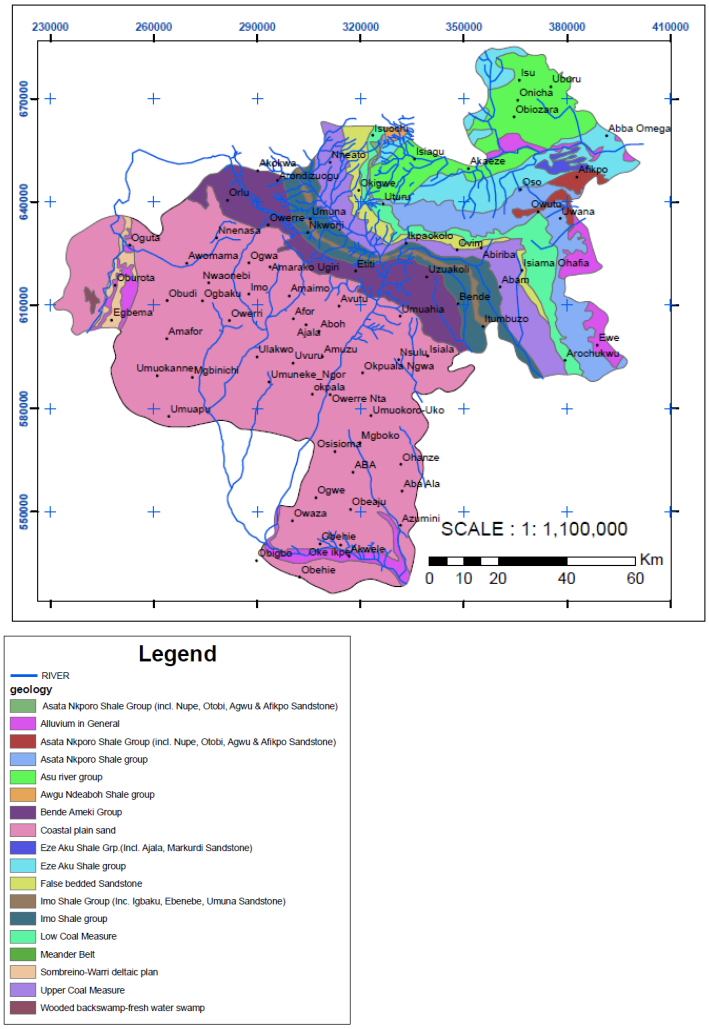

Figure 1: Geological map of the study area

Soil Analyses

Bulked soil samples collected were air-dried, gently crushed and passed through a 2-mm sieve to obtain fine earth separates. The processed soil samples were analyzed for some physico-chemical properties following procedures given by Van Reeuwijk (2002). Particle size analysis was done using the hydrometer method.Soil pH in 1:2.5 water suspension was measured with a pH meter. Organic carbon was measured by the Walkley and Black method. Available phosphorous (P) was determined according to Bray No. 2 method, and total nitrogen (N) was determined by the microKjeldahl digestion method. Bulk density was determined by the core method, CEC was determined by using the neutral ammonium acetate method, and base saturation was calculated.

Land Evaluation and Data Analysis

Means of the data generated from soil laboratory analyses were determined. Land suitability evaluation was carried out using the FAO's (1976; 1983) 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 characteristics 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 not suitable (N).

RESULTS AND DISCUSSION

Land Qualities/Characteristics of the Soils

The results of the land characteristics are presented in Table 1. The texture of the soils ranged from clay loam in Umuna soils (Imo clay shale) to sandy loam in Ihiagwa soils (coastal plain sands). It suggests that coastal plain sands and alluvium are sandier than soils derived from the Imo clay shale. High sandiness of soils developed on the coastal plain sands and alluvium could be attributed to the nature of their parent rocks and is a reflection of the characteristics of the acid

TABLE 1
Land qualities and characteristics of the soils

Parameters	Umuna (Imo clay shale)	Oguta (alluvium)	Ihiagwa (Owerri) (coastal plain sand)
Climate (C)			
Mean annual rainfall (mm)	2000-2500	2000-2500	2000-2500
Temperature (^{o}C)	27-30	27-30	27-30
Relative humidity (%)	80	80	80
Soil physical characteristics (S)			
Slope (%)	1.5	1.5	<1
Drainage	Moderately drained	Imperfectly drained	Excessively drained
Soil depth (cm)	200	157	200
Sand (g kg^{-1})	546	838	812
Silt (g kg^{-1})	120	33	20
Clay (g kg^{-1})	334	130	168
Soil texture	CL	LS	SL
Soil fertility (F)			
pH	6.12	6.49	5.13
Total nitrogen (g kg^{-1})	1.01	0.89	0.84
Available P (mg kg^{-1})	1.07	2.02	0.76
Organic C (g kg^{-1})	12.18	11.05	10.32
CEC ($cmol_{+}$ kg^{-1})	7.21	5.40	8.89
BS (%)	82.34	81.57	82.79

CL= clay loam, LS=Loamy sand, SL=Sandy loam, BS = Base saturation

sands of Southeastern Nigeria (Enwezor *et al*,. 1989). The coastal plain sands, which underlie the major part of Southeastern Nigeria, consist of unconsolidated yellow and white sand materials which are sometimes cross-bedded with clays, sand clays and sometimes pebbles (FDALR 1990; Edet *et al*., 1994). On the other hand, soils derived from the Imo clay shale are generally deep, moderately to imperfectly drained with dark gray sandy clay loam to clay loam surfaces underlain by dark brown to brown, sometimes mottled clay sub-soils (FDARL, 1990).

The pH values of the soils ranged from moderately acidic (5.13) to slightly acidic (6.49). The proportions of organic carbon in the soils investigated were low when compared with the critical level of 2% (20 g kg^{-1}) reported by Chude *et al*. (2011) in Nigerian soils. This may be due to the prevalence of tropical conditions where the degradation of organic matter occurs at faster rates, thereby leaving less organic carbon in the soils (Nayak *et al.*, 2002). Also, the available P contents of the soils of the different parent materials were given very low ratings as their P values were lower than critical levels of 10 – 16 mg kg^{-1} (Adeoye and Agboola, 1985) and 15 mg kg^{-1} (FPDD, 1990) for soils of southeastern Nigeria. Low available P obtained across the soils could be a reflection of the low organic carbon contents of these soils. Organic compounds in soils increase P availability by forming organophosphate complexes that are more easily assimilated by plants, replace $H_2PO_4^-$ with anions at adsorption sites, coat Fe/Al oxides with humus to form a protective cover, and reduce P fixation (Selassie and Ayanna, 2013). The influence of organic carbon in the soil on P availability has been reported by Idigbor etal. (2008). The nitrogen contents of the soils ranged from 0.84 g kg^{-1} in soils derived from the coastal plain sand to 1.01 g kg^{-1} in those derived from Imo clay shale. The low N contents of the soils may be as a result of the high N losses sustained in the soils through the leaching of nitrates, as well as the rapid mineralization of organic matter resulting from the exposure of soils to high temperatures (Senjobi and Ogunkunle, 2011; Mustafa *et al*., 2011; Uzoho *et al*., 2014).

Land Suitability Evaluation

When climatic requirements for groundnut and maize (FAO, 1976; FAO,1983) (Tables 2 and 3) were matched with land quality (rainfall and temperature) of the study area (Table 1), all the soils were highly suitable (S1) for groundnut and maize cultivation. These results indicated that the study area is currently ideal in terms of climate for the cultivation of both crops.

Soil physical characteristics considered for the cultivation of maize and groundnut were soil depth, texture, drainage and topography. Soil depth and topography were highly suitable for maize and groundnut cultivation at all the sites. Generally, the slope of <2% found by this study may favour mechanical operations (Lawal *et al*., 2012). However, soil texture was highly suitable for groundnut production in Ihiagwa (coastal plain sands) and Oguta (alluvium) but only moderately suitable (S2) for the cultivation of maize. The texture of Umuna soils (clay loam) made the soils highly suitable for maize production (Sys,

TABLE 2
Land requirements for Maize

Land Qualities/characteristics	Factor suitability rating: Highly suitable (S1)	Moderately suitable (S2)	Marginally suitable (S3)	Not suitable (N)
Climate (c)				
Rainfall (mm)	>800	700-800	600-700	<600
Temperature (^oC)	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})	>1.5	1.0-1.5	0.5-1.0	< 0.5
Available P (mg kg^{-1})	>40	10-40	3-10	< 3
CEC ($cmo1_{(+)}kg^{-1}$)	>25	13-25	6-13	< 6
Organic C (g kg^{-1})	>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.

TABLE 3
Land requirements for groundnut

Land qualities/characteristics	Factor suitability rating: Highly suitable (S1)	Moderately suitable (S2)	Marginally suitable (S3)	Not suitable (N)
Climate (C)				
Rainfall (mm)	>700	600-700	500-600	<500
Temperature (^oC)	22-28	18-22	15-18	<15
Soil physical characteristics (S)				
Soil depth (cm)	> 120	75-120	30-75	<30
Soil texture	SL, SiL, LS	CL,SiCL	S, SC, SiC	C
Topography (t)				
Slope (%)	0-2	2-5	5-8	>8
Drainage	Well drained	Moderately-well drained	Imperfectly drained	Poorly drained
Soil fertility status (f)				
pH	5.8-6.2	5.5-5.7 6.3-6.5	5.0-5.4, 6.6-7.0	<5, > 7
Total N (g kg^{-1})	>0.5	0.2-0.5	0.2	<0.2
Available (mg kg^{-1})	>20	10-20	5-10	<0.5
CEC ($cmol_{(+)}$ kg^{-1})	>12	6-12	4-6	<64
Base saturation (%)	>80	50-80	40-50	<40
Organic C (g kg^{-1})	>12	8-12	5-8	<5

Source: FAO (1983).
LS = Loamy Sand, SL = Sandy Loam, CL = Clay loam, SiL = Silt Loam, SiCL = Silt Clay Loam, C-Clay , S = Sand, SC = Sandy Clay.

1983; FAO, 1983). For soil wetness (drainage), the results of matching the crop requirements with land characteristics showed that soils derived from coastal plain sands were highly suitable, whilst those of the Imo clay shale were only moderately suitable for the cultivation of maize and groundnut. Soils derived from alluvium were marginally suitable (S3) for groundnut and maize production. For soil fertility characteristics, available P was a serious constraint to both maize and groundnut cultivation in the study areas as the values were low when compared with the requirements of both crops (FAO, 1976; FAO, 1983). Total N was highly suitable for the cultivation of groundnut in the soils derived from the three different lithological materials. In soils derived from Imo clay shale, total N was moderately suitable (S2) whilst in those derived from alluvium and coastal plain sands, it was marginally suitable (S3) for maize cultivation. The organic carbon contents of the soils made the soils highly suitable (S1) in soils derived from the Imo clay shale, but moderately suitable (S2) in soils derived from alluvium and coastal plain sands for groundnut cultivation. Generally, soils derived from the three different parent materials were moderately suitable (S2) for maize production when the organic carbon requirement of the crop (Table 2) matched the organic carbon contents of the soils (Table 1). Base saturation was optimum for both maize and groundnut cultivation in all the sites (Tables 4 and 5). For soils from Umuna and Oguta, pH was optimum (S1) whilst soil from Ihiagwa was marginally suitable for maize cultivation. Also, soils from Umuna (Imo clay shale), Oguta (alluvium) and Ihiagwa (coastal plain sands) were optimum, moderately suitable and marginally suitable, respectively, for groundnut production when the pH requirement of the crop matched those of the

TABLE 4
Suitability assessment of the soils for maize production

Land Parameters	Umuna (Imo clay shale)	Oguta (Alluvium)	Ihiagwa (Coastal Plain sand)
Climate (c)			
Mean annual rainfall (mm)	S_1	S_1	S_1
Temperature (^oC)	S_1	S_1	S_1
Soil characteristics physical (s)			
Soil depth	S_1	S_1	S_1
Soil texture	S_1	S_2	S_2
Topography (t)			
Slope	S_1	S_1	S_1
Drainage	S_2	S_3	S_1
Soil Fertility (f)			
pH	S_1	S_1	S3
Total N	S_2	S_3	S_3
Available P	N	N	N
Organic Carbon	S_2	S_2	S_2
BS	S_1	S_1	S_1
CEC	S_2	S3	S_2
Overall Suitability	N(f)	N(f)	N(f)

S_1 = highly suitable, S_2 = moderately suitable, S_3 = marginally suitable, N = Not suitable, Limitations (restrictive features): S = soil characteristics, f = fertility limitation, T = topography, W = wetness/drainage

sites.

From the results of the aggregate suitability, all the soils were currently not suitable for the cultivation of both maize and groundnut. The major land characteristic limiting the cultivation of these crops was soil fertility, constrained

TABLE 5
Suitability assessment of the soils for groundnut production

Land parameters	Umuna (Imo clay shale)	Oguta (alluvium)	Ihiagwa (coastal plain sand)
Climatic (C)			
Mean annual rainfall (mm)	S_1	S_1	S_1
Temperature	S_1	S_1	S_1
Soil physical characteristics (S)			
Soil depth	S_1	S_1	S_1
Soil texture	S_2	S_1	S_1
Topography (t)			
Slope	S_1	S_1	S_1
Wetness (W)			
Drainage	S_1	S_2	S_1
Soil fertility (f)			
pH	S_1	S_2	S3
Total N	S1	S1	S1
Available P	N	N	N
Organic carbon	S_1	S_2	S_2
BS	S_1	S_1	S_1
CEC	S_2	S_3	S_2
Overall suitability	N(f)	N(f)	N(f)

S_1 = highly suitable, S_2 = moderately suitable, S_3 = marginally suitable, N = Not suitable, Limitations (restrictive features): S = soil characteristics, f = fertility limitation, T = topography, W = wetness/drainage.

by P availability.

CONCLUSION

The investigation of land qualities such as mean annual rainfall, temperature, soil depth, slope and base saturation of the soils investigated showed that they were currently highly suitable for both maize and groundnut production. However, P availability rendered all the soils unsuitable for maize and groundnut production, irrespective of their parent materials. Therefore, in order to enhance the productivity level of the land to the optimum level for maize and groundnut production, proper agronomic practices should be carried out to improve the fertility of the soils. As P deficiency was the most important limiting factor, it needs to be alleviated so as to sustain maize and groundnut production in thesoils tested.

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