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SUITABILITY EVALUATION OF SOILS OF THE COASTAL PLAIN SANDS FOR RAIN-FED MAIZE PRODUCTION IN ACID SANDS OF SOUTH-EASTERN NIGERIA.

***Ahukaemere, C.M.,[1]Onweremadu, E.U.,[1] Akamigbo, F.O.R.,[2] Ndukwu, B.N.[1]**

[1]*Department of Soil Science and Technology, Federal University of Technology, P.M.B. 1526, Owerri, Imo State, Nigeria.mildredshine@yahoo.com*

[2]*Department of Soil Science, University of Nigeria, Nzukka.*

ABSTRACT

Soils developed on Coastal plain sands have been classified as acidic soils of low CEC and soil fertility. These fragile sandy soils were evaluated for effective and sustainable rain-fed maize production using FAO land suitability classification system. Profile pits were consequently dug in four different soil units – 100m apart: Umuagwo soil unit 1, 2, 3 and 4 respectively. Results indicated that soils had sandy topsoil and more clayey subsoil. Rainfall, temperature, soil depth, drainage and organic carbon contents of the different soil units were favourable for maize production. Available phosphorus and percentage base saturation were rated moderately suitable for maize production. Cation exchange capacity and total nitrogen contents of the soils made the varying soil units marginally suitable for maize production. The overall suitability ratings of the soils indicated that soil units 1, 3 and 4 were not suitable (Nf) for rain-fed maize production because of fertility (pH) limitation. Soil unit 2 was rated marginally suitable (S3f) for maize production with fertility (total nitrogen, pH, CEC) constraint as the major limitation. These fertility limitations can be corrected by adequate liming, nitrogen fertilizer application and other management practices that boost the cation exchange capacity of soil.

INTRODUCTION

Nigeria's landmasses are facing intensive competitive use that very often leads to their misuse and degradation due to increasing demand for food as a result of rapid population expansion. This in effect hinders meaningful national development. It is therefore, pertinent that for the potentials of agricultural land to be maximized, there is need to have an understanding of the suitable options the land can be put into. Land use ought not to be based on the need and demand of the users; rather land use decisions should be based on an understanding of the best uses to which the land can be put into. In other words an effective land use planning is hinged on having qualitative and quantitative information on the land.

Coastal Plain Sands, which underlie a major part of Owerri, South-eastern Nigeria consists of unconsolidated sand materials which are sometimes cross-bedded with clays, sandy clays and sometimes, pebbles (Orajaka, 1975; FDALR, 1985). Soils on the Coastal Plain Sands are deep, highly weathered, strongly acidic, coarse-textured, easily eroded and generally of low inherent chemical fertility (Eshett, 1991; Osuji *et al.*, 2002). This inherent low fertility and poor structural stability necessitate the need for effective management and sustainable use. Unfortunately, the poor management and land use planning of these soils have resulted in the extent and magnitude of the gully erosion that now devastate Owerri; a problem compounded by the very high annual rainfall recorded in the region.

In the face of these disturbing realities, the importance of a soil survey and land suitability evaluation of the region cannot be over emphasized. It is indeed a prerequisite for the sustainable use and management of this limited resource. As such, while we are still strongly advocating for the conduct of a detailed and / or semi-detailed soil survey of Owerri agricultural zone for effective and sustainable agricultural development, in the light of the extent of soil degradation in the area interim actions must be taken to forestall further deterioration. Therefore, the major objective of this study is to evaluate the suitability of some soils developed on the Coastal plain sands for rain-fed maize production.

MATERIALS AND METHODS

Study Area: The study area is located between latitudes 5^0 53'N and longitudes 7^0 54'E. The geology of the study area is Coastal plain sands. Umuagwo-Ohaji is a humid tropical climate with a mean annual rainfall of 1700 - 2250 mm distributed to about 139 days of the year. It is double maxima, with an August break occurring in July or August and high relative humidity (above 80 %) during the rainy season (Ofomata, 1975). The mean annual temperature ranged from 24 – 30 ^{0}C. As agriculture is the major socio-economic activity of the area, about 70 % of the total areas is used for crop production.

Filed Study

A transect survey technique was used to align the different study sites, confined within Umuagwo Ohaji-Egbema at an equidistance of 100 m. A profile pit was sunk in each site (soil unit) giving total of four (4) profile pits. These profile pits were examined according to FAO (2006) guidelines. Bulk soil samples were collected from various identified genetic horizons of the profiles and analyzed in the laboratory.

Soil Analysis

Bulked soil samples collected were air-dried, gently crushed and passed through 2 mm sieve to obtain fine earth separates. The processed soil samples were analyzed for some physico-chemical properties following procedures outlined by FAO (2002). Briefly, particle size analysis was determined by hydrometer method, soil pH in 1:2.5 water suspension was measured with pH meter and organic carbon by Walkley and Black method. The available P was determined according to Bray No. 2 method, total N was determined by micro Kjeldahl digestion method. Bulk density was determined by Core method, CEC was by use of neutral ammonium acetate method and Base Saturation by calculation.

Land Evaluation and Data analysis

Means of the data generated from soil laboratory analyses were calculated. The land suitability evaluation was carried out using guidelines for land evaluation as described by FAO (1976) (1983). 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 Nitrogen, cation exchange capacity and base saturation. The identified soil units were placed in suitability classes by matching their characteristics with requirements of the test crop. The most limiting characteristics dictated overall suitability for each soil. The suitability of each factor for respective soil unit was classified as highly suitable (S1), moderately suitable (S2), marginally suitable (S3) and not suitable (N).

RESULTS AND DISCUSSION

Soil Characteristics of the Study Area

The selected morphological and physical properties of the soils are presented in Table 1. The textures of the different soil units ranged from sand, sandy loam to loamy sand. The textures of these soils reflected the parent rocks from which they are formed. Several authors linked soil texture to the nature of parent materials from which the soils are derived and also to the rate and nature of some weathering processes (Ahukaemere *et al.,* 2012 and Akamigbo *et al.,* 1999). Texture is strongly correlated with soils ability to percolate water, how much water the soil can store and the soils ability to absorb or desorb chemical ion (exchange capacity). All the soil units were well drained and may be attribute to their sandy texture. The mean bulk density values of the varying soil units ranged from 1.22 – 1.53 gcm^{-3} and were lower than the critical value (1.75 – 1.85 gcm^{-3}) which root restriction can occur on sandy loam soils (Soil Survey Staff, 1996). From the bulk density results, soils were not compacted and can encourage root penetration and good crop yield.

Table 1: Some Morphological and Physical properties of varying soil units

Horizon	Depth (cm)	Colour (moist)	Sand (gkg^{-1})	Silt (gkg^{-1})	Clay (gkg^{-1})	Texture	Drainage	BD (gcm^{-3})
			Soil unit 1					
A	0-15	5YR 3/2	878.00	94.00	28.00	S	WD	1.23
AB	15-58	5YR ¾	878.00	54.00	68.00	S	WD	1.23
Bt1	58-105	5YR 4/4	848.00	44.00	108.00	LS	WD	1.36
Bt2	105-150	5YR 4/4	758.00	44.00	198.00	SL	WD	1.42
Bt3	150-200	2.5YR 5/8	778.00	54.00	169.00	SL	WD	1.57
	Mean		828.00	58.00	114.20			1.36
			Soil unit 2					
A	0-11	5YR 2/3	878.00	64.00	58.00	LS	WD	1.44
AB	11-31	5YR 4/2	898.00	54.00	48.00	S	WD	1.43
Bt1	31-86	2.5YR 4/2	858.00	94.00	48.00	LS	WD	1.44
Bt2	86-121	2.5YR 4/8	838.00	64.00	98.00	LS	WD	1.61
Bt3	121-154	2.5YR 4/8	818.00	54.00	128.00	LS	WD	1.61
Bt4	154-200	5YR 5/8	818.00	34.00	148.00	LS	WD	1.62
	Mean		851.33	60.67	88.00			1.53
			Soil unit 3					
A	0-18	7.5YR 4/1	848.00	69.00	83.00	LS	WD	1.14
AB	18-47	5YR 5/4	838.00	54.00	108.00	LS	WD	1.16
Bt1	47-107	7.5YR 5/6	758.00	64.00	178.00	SL	WD	1.19
Bt2	107-142	7.5YR 5/6	778.00	34.00	188.00	SL	WD	1.29
Bt3	142-200	5YR 5/8	778.00	24.00	198.00	SL	WD	1.34
	Mean		800.00	49.00	151.00			1.22
			Soil unit 4					
A	0-14	7.5 YR 3/3	878.00	74.00	48.00	LS	WD	1.44
AB	14-56	2.5YR 4/3	878.00	54.00	68.00	LS	WD	1.43
Bt1	56-97	5YR 4/4	848.00	64.00	98.00	LS	WD	1.43
Bt2	97-149	2.5YR 4/6	778.00	54.00	168.00	SL	WD	1.50
Bt3	149-200	2.5YR 4/8	758.00	44.00	198.00	SL	WD	1.66
	Mean		828.00	58.00	116.00			1.49

Soil pH values were low (4.52 – 5.71) when compared with the range of 5.5 – 6.5 where most essential nutrients are optimally available to plants (Halving *et al.,* 2005; Lake, 2000). Such reaction is characteristic of soils in South-eastern Nigeria and it is as a result of the acidic nature of the lithological material, coupled with the influence of the leached profile under high annual rainfall condition (Eshett *et al.*, 1990). According to the ratings of Esu (1991), soils were low to moderate in organic carbon (8.32 – 13.04 gkg^{-1}), moderate (> 6.00 $cmolkg^{-1}$) in CEC and very low (0.64 – 0.81 gkg^{-1}) in total nitrogen. Osuji *et al.* (2002) reported that soils formed from the Coastal Plain Sands are deep, strongly acidic, coarse-textured and generally of low CEC and inherent chemical fertility. Available P contents of soils were higher than the critical value of 15 $mgkg^{-1}$ reported by Enwezor *et al.,* (1990) for soils of South-eastern Nigeria. Exchangeable sodium percent (ESP) which identifies the degree to which the exchange complex is saturated with Na was very low (1.46 – 2.11 %). Low ESP obtained from this study across all the different soil units may be a consequence of low sodium content, rainfall pattern and the acidic conditions of the soils. ESP levels of 15 % is associated with pH values of 8.5 and above. Concisely, forest soils with higher pH values had high exchangeable sodium percentage indicating the influence of soil pH on sodium percentage.

Table 2: Chemical properties of the varying soil units

Horizon	Depth (cm)	pH (H2O)	OC (gkg^{-1})	TN (gkg^{-1})	CEC ($cmolkg^{-1}$)	BS (%)	AVP ($mgkg^{-1}$)	ESP (%)
			Soil unit 1					
A	0-15	4.47	15.51	0.30	10.14	64.00	17.40	0.61
AB	15-58	4.42	9.74	1.00	10.11	50.00	20.90	3.55
Bt1	58-105	4.81	6.80	0.60	5.96	75.00	19.30	1.55
Bt2	105-150	4.56	5.14	0.60	6.10	81.00	20.90	2.00
Bt3	150-200	5.00	4.40	0.71	5.58	75.00	21.90	2.84
	Mean	4.65	8.32	0.64	7.58	69.00	20.08	2.11
			Soil unit 2					
A	0-11	4.17	15.91	1.20	7.76	75.26	18.10	1.88
AB	11-31	4.45	11.12	1.21	7.96	77.51	17.80	1.13
Bt1	31-86	6.03	8.10	0.82	9.04	78.21	16.10	1.84
Bt2	86-121	5.30	7.00	0.82	5.65	81.59	17.10	2.17
Bt3	121-154	5.02	5.44	0.06	8.02	77.06	17.50	0.97
Bt4	154-200	5.11	5.10	0.60	9.12	83.00	18.34	0.79
	Mean	5.71	8.78	0.79	7.93	78.77	17.49	1.46
			Soil unit 3					
A	0-18	4.42	35.26	1.70	8.32	80.71	23.08	1.66
AB	18-47	4.31	9.00	0.60	7.01	72.61	17.50	1.71
Bt1	47-107	4.26	7.83	0.60	6.21	74.07	19.00	2.61
Bt2	107-142	5.18	6.80	0.61	6.84	82.51	16.10	1.56
Bt3	142-200	4.44	6.32	0.50	7.57	82.24	18.71	1.44
	Mean	4.52	13.04	0.80	7.19	78.43	18.89	1.80
			Soil unit 4					
A	0-14	5.47	16.70	1.10	9.12	83.00	20.40	0.79
AB	14-56	5.42	9.20	0.81	9.04	78.21	20.90	1.84
Bt1	56-97	4.89	7.90	0.92	5.65	81.59	19.330	2.17
Bt2	97-149	4.95	6.30	0.40	7.76	75.26	22.90	2.04
Bt3	149-200	5.88	4.80	0.83	8.02	77.06	21.90	0.97
	Mean	5.32	8.98	0.81	7.92	79.02	21.09	1.56

OC = organic carbon, TN = Total Nitrogen, CEC = Cation exchange capacity, BS = Base saturation, ESP = Exchangeable Sodium percentage, Av.P = Available phosphorus

Table 3: Land requirement for suitability classes for rain-fed maize

	Factor suitability rating			
Land Qualities/ characteristics	**Highly suitable (S1)**	**Moderately suitable (S2)**	**Marginally suitable (S3)**	**Not suitable (N)**
Climate (c)				
Rainfall (mm)	> 800	700-800	600-700	< 600
Temperature (^{0}C)	24-30	20-24	15-20	< 15
Land /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
Wetness (w)				
Drainage	Well drained	Moderately drained	imperfect	Poor, very poor
Fertility status (f)				
pH	6.0-6.5	5.5-6.0	5.0-5.5	< 5.0
Total N (gkg^{-1})	>1.5	1.0-1.5	0.5-1.0	< 0.5
Available P (mgkg^{-1})	>40	10-40	3-10	< 3
CEC (cmolkg^{-1})	>25	13-25	6-13	< 6
Organic C (gkg^{-1})	> 2.0	1.0-2.0	0.5-1.0	< 0.5
Base saturation (%)	>80	40-80	20-40	< 20

Source: FAO (1976; 1983).

CL = Clay laom, L= Loam, SL = Sandy loam, LS= Loamy sand, LCS = Loamy coarse sand, CS = Coarse sand.

Table 4: Land qualities/characteristics of the study sites

Parameters	**Soil unit 1**	**Soil unit 2**	**Soil unit 3**	**Soil unit 4**
Mean annual rainfall (mm)	>1800	>1800	>1800	>1800
Temperature (^{0}C)	>24	>24	>24	>24
Slope (%)	<1	<1	1.5	<1
Drainage	Well drained	well drained	Well drained	well drained
Soil depth (cm)	200	200	200	200
Soil Texture	LS	LS	LS	LS
pH	4.65	5.71	4.52	5.32
Total N (gkg^{-1})	0.64	0.79.	0.80	0.81
Available P (mgkg^{-1})	20.08	17.49	18.87	21.09
Organic C (gkg^{-1})	8.32	8.78	13.04	8.98
CEC (cmolkg^{-1})	7.58	7.93	7.19	7.91
%BS	69	79	78	79

Land Suitability Classification for maize

A summary of land characteristics/qualities of the study sites is shown in Table 4 and the assessment rating resulting from matching of land qualities and the requirements for the test crop is presented in Table 5. The climatic condition of the study area (temperature and rainfall) were highly suitable (S1) and favourable for maize production as values were higher than 800 mm and 24 ^{0}C (Table 3) (FAO 1976, 1983). The slope of 0-1.5 % made all the soil units highly suitable (S1) for maize. Generally, slope of < 2 % reported in this study may favour mechanical operations. Lawal *et al.* (2012) reported the influence of slope on farm mechanization. All the soil units were properly drained which made them highly suitable (S1) for maize cultivation and could be due to the texture of the soils which had low water retention capacity. Regarding soil depth, all the soil units were highly suitable (S1) while soil texture made the soils to be moderately suitable (S2) for maize production. Considering CEC and total N contents of the soils, soils were generally marginally suit-

Table 5: Suitability assessment of the study sites for rain-fed maize

Land parameters	Soil unit 1	Soil unit 2	Soil unit 3	Soil unit 4
Climate (c)				
Mean annual rainfall (mm)	S1	S1	S1	S1
Temperature	S1	S1	S1	S1
Soil characteristics (s)				
Soil depth	S1	S1	S1	S1
Soil texture	S2	S2	S2	S2
Topography (t)				
Slope	S1	S1	S1	S1
Wetness (w)				
Drainage	S1	S1	S1	S1
Fertility status (f)				
pH	N	S3	N	S3
Total Nitrogen	S3	S3	S3	S3
Available P	S2	S2	S2	S2
Organic Carbon	S1	S1	S1	S1
BS	S2	S2	S2	S2
CEC	S3	S3	S3	S3
Overall Suitability	N (f)	S3 (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 /oxygen availability limitation.

able (S3) and may require Nitrogen fertilizer application for sustainable maize production. Regarding organic carbon, all the soil units studied were highly suitable while available P and base saturation made the soils moderately suitable for optimum maize production. In terms of pH requirement for the test crop (6.0 – 6.5) (Table 3), Umuagwo soil units 1 and 3 were not suitable (N) while soil unit 2 and 4 were marginally suitable (S3) for maize cultivation.

In terms of overall suitability rating, Umuagwo soil units 1, 3 and 4 were rated not suitable (N(f)) with soil fertility as major limitations. Soil unit 2 also had soil fertility characteristic (f) as a limitation and was rated marginally suitable (S3(f)) for maize production (Table 5).

CONCLUSION

The suitability assessment result showed that although certain land characteristics such as mean annual climatic factors (rainfall and temperature), topography, drainage, soil depth and organic carbon were optimum for maize performance, non of the soil units was highly suitable for maize cultivation. The major limitations in all the soil units evaluated were fertility limitations. Therefore, to ensure optimum maize performance in the area, proper management practices that will enhance the fertility status of the area should be adopted.

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