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SUITABILITY ASSESSMENT OF SOILS AROUND FORESTRY RESEARCH INSTITUTE OF NIGERIA (FRIN), IBADAN FOR MAIZE PRODUCTION: A PARAMETRIC ANALYSES

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Abstract
The sustainable use of soil resources requires extensive knowledge about its morphology and other properties. The study was carried out to evaluate the suitability of soils for maize production in Forestry Research Institute of Nigeria's (FRIN), environment, Ibadan, using the parametric method. Four profile pits were dug, described and the soil samples collected and analyzed for particle size distribution, pH, organic matter, total nitrogen, available phosphorus, exchangeable acidity, exchangeable bases and extractable micro nutrients. The textures of the soils were loamy sand, sandy loam and sandy clay loam which varied in response to changes in slope and drainage position. The soil's pH ranged from strong to slightly acidity (4.32 – 6.75). Organic matter (17.2 -61.2g kg^{-1}), total exchangeable base and total nitrogen (0.7 – 3.1g kg^{-1}) were high, while the extractable micro nutrients; Fe (37 – 67mg kg^{-1}), Cu (7 – 13mg kg^{-1}), Mn (5 – 142mg kg^{-1}) and Zn (38 -134mg kg^{-1}) were at toxic level. Suitability evaluation of the soil using parametric approach shows that the soils are presently not suitable (NS) for the cultivation of maize, while, the potential of suitability of the soil for maize cultivation was ranked marginally suitable (S3). The soils of the study area were classified as Egbeda association which is not currently suitable for maize production, because of its present status. However, the soils suitability potential can be improved through conservative agronomic practices and also to prevent rapid degradation.

Keywords: Suitability, assessment, maize, parametric method, soil, FRIN

Introduction
Inadequate knowledge of the importance of the suitability and capability assessment of agricultural land remains one of the major problems of agricultural production in developing countries, especially sub-Saharan Africa; this results in poor agronomic practices, low yield and high cost of production (Aderonke and Gbadegesin, 2013). Understanding land capacity for optimization and the sustainability of its productivity otherwise called "Evaluation", (Adeboye, 1994) requires an extensive knowledge about its genesis, morphology and properties. In order to assess the suitability of soils for a particular crop production, the crops requirement must be known (Ande, 2011), prevailing soil conditions and other factors including climate, soil, topography and hydrology (Adesemuyi, 2014) are requisite. Therefore, soil suitability classifications are based on matching requirements for crops with soil properties. Maize (*Zea mays L.*) is among the important cereal crop in sub-Saharan Africa, it is an important staple crop that plays dominant roles in the economy of southwestern Nigeria. Worldwide, production of maize is about 785 million tons, and the United States of America being the largest producer with about 42%, while Africa produce 6.5%. The largest producer of maize in Africa is Nigeria with nearly 8 million tons (IITA, 2009). The current soil degradation issues as a result of increasing population, industrialization and over-grazing amongst other factors have led to limited soil productivity and capacity to sustain maize production in Nigeria. Therefore, soil characterization and land evaluation for agricultural use becomes an important approach for achieving food security and a sustainable environment. The objective of this study was to evaluate and characterize the suitability of the study area for maize using the parametric method.

Materials and Methods
The research was conducted at Forestry Research Institute of Nigeria, Jericho hill, Ibadan, Oyo State located on latitude 7.23°N and longitude 3.51°E; annual rainfall of 1250mm with a bimodal pattern and an average temperature of 26°C. Free survey method was adopted for the identification of the soil units. Four profile pits were established at different mapped areas

within the institute's field. The morphological properties of the pedon were described using the criteria of the soil survey division staff (SSS, 1990) and the guidelines for soil profile description (FAO-UNESCO, 2006). Soil samples were taken from pedogenic horizons or layers of the profiles for laboratory analysis.

Laboratory analyses

The soil samples collected were properly labeled, air-dried, gently crushed and sieved with a 2mm sieve. Particle size analysis was done using the Bouyoucos hydrometer method (Bouyoucos, 1965) as modified by (Gee and Or, 2002). The soil pH was determined in water with a digital pH meter (Peech *et al.,* 1996). Organic matter was determined using the Walkley-Black chromic acid digestion method by Nelson and Sommers (1996). Total N was determined according to Kjeldahl method (Bremner and Mulvaney, 1982). Available P was extracted using Mehlich method (Mehlich, 1984). Exchangeable bases (K, Ca, Na and Mg) were extracted using mehlich solution, Na and K concentration of the extract was determined by flame photometer, while, Mg and Ca were determined using atomic absorption spectrophotometer. Exchangeable acidity was determined using 1N KCl extraction and titrated with 0.05 N NaOH to determine extractable Al^{3+} and H^{+}, and re-titrated with 0.05 N HCl solution (McLean, 1965). The extractable micronutrient (Fe, Mn, Cu and Zn) were extracted with 0.5 N ethylene-di-amine-tetra-acetic acid (EDTA) and concentration of each element was determined using atomic absorption spectrophotometer.

Land suitability parametric method

Land suitability evaluation of the soil was done using the parametric method (Sys *et al*., 1991) and by combining the recognizable land characteristics on the field with those determined in the laboratory. The following are the land qualities and characteristics used for the evaluation; rainfall, mean temperature, slope, drainage and texture, soil depth, fertility, cation exchange, base saturation and organic carbon.

Land indices were calculated using the equation developed by Storie (1978):

$$\mathrm{Si} = 1 + \frac{\mathrm{A \times B \times C}}{1000} \ldots . \mathrm{n}$$

Where,

S_i = Index of suitability

A = Index of the most limiting characteristic

B = Index of topography

C = Index of moisture availability

n = Index of nth characteristic.

The index of suitability (S_i) was then converted to suitability class using Sys (1978) conversion. The land characteristics and corresponding suitability used for assessing maize is presented in Table 1. The index of suitability for maize for each profile was also calculated as shown in the table.

Results and Discussion

Morphology site Description

Table 2 shows the morphological properties of all the four pedons at the study area. The results indicate that the soil pedons have structures that ranged from weak, fine crumb, sub angular blocky peds (Wfcrsbk) in the surface horizon, to strong coarse sub angular blocky peds (Scrsbk) in the subsurface soil; with a very distinct to clear and wavy boundaries from surface to subsurface horizons respectively. This can be attributed to melanization by organic matter in the Ap horizons. The consistence of the pedons varied from non-sticky (NS) to non-plastic (NP) and slightly sticky (SS) in the surface and subsurface horizons. This may be due to low illuviation of clay in the pedons at the surface and sub surface diagnostic horizons (Esu, 1999). The soil texture revealed that the pedons were mostly loamy sand in the surface horizons to sandy loam and sandy clay loam in the subsurface horizons. This explains why the consistence of the soil is slightly sticky at the subsurface horizons.

Particle size distribution and chemical properties of the soil

Table 3 and 4 show the particle size distribution and chemical properties of the soils of the study area. The clay content of the soil from all profiles ranged between 12.1 to 26.3%. It was observed that the clay content values at the subsurface horizons were higher in all the profiles. This increase with depth can be attributed to illuviation; that is, clay migration and erosion from the soil surface layer into the subsurface horizon, which results in argillic horizons (Esu, 1987; Maniyunda, 1999). The sand content varied from 68.7 to 86.9%. The surface horizon of profile 3 had the highest sand content, while the subsurface horizon of profile 4 had the least value of sand content. It was observed that sand content was higher at the surface horizon of all the profiles. In contrary to clay content, sand content decreased with depth. The silt content was between 18 and 103%. The values for subsurface and surface horizon for each profile varied and were inconsistent. The highest value was observed at the subsurface horizon of profile 2, while the lowest value was recorded at the surface horizon for profile 3. The soil textural class was largely sandy loam and sandy clay loam. The overall characteristics of the soil content were high sand and low silt, following Nsor and Ibanga (2007). Soil pH values range from strongly acidic (4.32) to mildly acidic at (6.75). The pH decreased with depth with exception to an increase in profile 2. The organic carbon content of the soil ranged from low (<10) to high (>15). The surface horizon in profiles 3 and 4 had higher value of OC compared to the subsurface horizons. The O.C content at the surface horizon ranged from 9.9 - 35.5g/kg, while, subsurface horizons value ranged from 18 - 34.1g/kg. The result also revealed that soils derived were low to very high in total nitrogen with values ranging from 0.7 to 3.1g/kg respectively. These high values are due to litter droppings from the trees and their Nitrogen fixation activities. Also, better positive effects are expected in the long run in terms of the soil physical characteristics (structure, texture, bulk density, porosity, water holding capacity, permeability/hydraulic conductivity) and chemical properties (pH, organic matter, total nitrogen, available phosphorus, K, Ca, Mg, Na, Zn, Cu, Mn, exchangeable acidity, cation exchange capacity)(Kareem, 2017). The study also indicated that available phosphorus content ranged from 1.04 to 52.42mg/kg, and was rated low to high. Amongst the exchangeable cation, calcium ranged from 0.23 to 7.36cmol/kg, rated low to high, magnesium ranged from 5.51 to 46.46cmol/kg rated medium to very high; potassium ranged from 1.2 to 4.44coml/kg, rated very high; while, sodium ranged from 0.6 to 7.9cmol/ kg and was rated very high, following Nsor and Ibanga (2007).

Summary of the land characteristics and suitability for maize production

Table 5 shows the summary of the land characteristics and land qualities of the study area for maize production. Annual rainfall of the study area is 1145mm, and optimum for maize production. The soils that occupied the topographical sites deep depth was 150 cm, an indication that the water table is below 200cm. The soils of all the profiles under investigations were well drained, with moderate- slope (1.6-2%), and fertility.

Table 1: Land requirement and suitability classes for maize production

	Land characteristics	SI1 100	SI2 95	S2 85	S3 60	N1 40	N2 25
	Topography (t)						
(a)	Slope (%)	0-2	2-4	4-8	8-16	16-20	>20
(b)	Slope (%)	0-4	4-8	8-16	>16	-	-
	Moisture availability (c)						
	Total rainfall during the growing season (mm)	800-1200	700-800	600-700	500-600	<500	-
	Oxygen availability (w)						
	Drainage	Good	Moderate	imperfect/rapid	poor/very excess	poor but drainable	poor but not drainable
	Nutrient availability (0-20cm) (f)						
	Total N (%)	>0.15	0.08-0.15	0.08-0.04	0.02-0.04	<0.02	any less
	Avail P (mg/kg)	>22	13-22	6-13	3-6	<3	any less
	Extractable K (meq/100g soil)	>0.5	0.3-0.5	0.2-0.3	0.1-0.2	<0.1	Any
	Mn (mg/kg)	>20	15-20	12-15	5-12	<5	Any
	Zn (mg/kg)	>15	12-15	8-12	3-8	<3	Any
	Cu (mg/kg)	>10	6-10	4-6	1-4	<1	Any
	Nutrient retention capacity (n)						
(c)	ECEC (meq/100g soil)	>15	10-15	5-10	3-5	<3	Any
(d)	ECEC (meq/100g clay)	>24	16-24	8-16	<8	-	-
	Base saturation						
	(c) (%)	>80	30-50	35-50	20-50	<20	-
(d)	(%)	>70	50-70	35-70	<35	-	-
	Organic matter						
	(c) (%)	>3	1-3	0.8-1	0.4-0.8	<0.4	-
	Physical soil characteristics						
	Texture/structure Gravel	CL	SC, SCL, L	SL, LS	LS, fS	Cm, S, cS	-
	(ac) (%)	<15	15-40	40-60	60-75	75-90	>90
	(b) (%)	<40	40-75	75-80	80-90	>90	-
(e)	(%)	<20	20-40	40-75	>75	-	-
	Soil depth (cm)	>90	50-90	30-50	20-30	10-20	<10
	Bulk density (g/cm^3)	<1.0	1.0-1.21	1.22-1.51	1.51-1.63	1.63-2	>2

Source: FAO (2006)

a = mechanized; b = non-mechanized; c = AP or A horizon, d = B or sub horizon; CL = clayloam; S = sand; SC = sandy clay; SCL = sandy clay loam; L = loam; cS = coarse sand; SL = sandy loam; LS = loamy sand; fS = fine sand; Cm = massive clay.

Table 2: Morphological description of the soils of the study area

Horizon	Depth (cm)	Texture	Structure	Consistency	Boundary	Features
Profile 1						
Ap	0-17	LS	Wfcrsbk	NS	Vd	Cmfr
AB	17-95	SL	Mmsbk	Sssp	D	Fine root
B	95-150	SL	Scsbk	Sssp	Cwb	Few fine root
Profile 2						
Ap	0-20	SCL	Wfcrsbk	NS	D	Presence of all types root
AB	20-56	SL	Msmsbk	NS	D	Many medium roots
B_1	56-127	SL	Scsbk	NS	Cwb	Few fine roots
B_2	127-180	SCL	Scrsbk	NS	Cwb	Devoid root
Profile 3						
Ap	0-28	LS	Msmsbk	NP	D	Mcfr
AB	28-108	SCL	Scrsbk	NS	D	Fine roots
B	108-150	SCL	Scrsbk	SS	Cwb	Few fine roots
Profile 4						
Ap	0-15	LS	Mfcrsbk	NP	D	Medium fine root
AB	15-54	SL	Scrsbk	NS	D	Fine roots
B	54-150	SCL	Scrsbk	SS	Cwb	Few fine roots

LS = loamy sand, SL= sandy loam, SCL = sandy clay loam, Wfcrsbk = weak, fine crumb, sub angular blocky, Scrsbk = strong coarse sub angular blocky, Wmcrsbk = weak, moderate, crumb sub angular blocky, Scsbk = strong, coarse sub angular blocky, Mfcrsbk = medium fine crumby sub-angular blocky, msmsbk = moderately strong medium sub angular blocky. NS = non-sticky, SS=slightly sticky, NP = non-plastic, SP = slightly plastic, D=distinct, Cwb = clear wavy boundary

Table 3 : Particle size distribution of the soils of the study area

Horizon	Depth (cm)	Sand (g/kg)	Silt (g/kg)	Clay (g/kg)	Textural class
Profile 1					
Ap	0-17	816	63	121	Loam sand
AB	17-95	816	63	121	Sandy loam
B	95-150	766	53	181	Sandy loam
Profile 2					
Ap	0-20	736	53	211	Sandy clay loam
AB	20-56	789	58	153	Sandy loam
B_1	56-127	756	103	141	Sandy loam
B_2	127-180	70	39	261	Sandy clay loam
Profile 3					
Ap	0-28	869	18	103	Loam sand
AB	28-108	70	37	263	Sandy clay loam
B	108-150	699	88	213	Sandy clay loam
Profile 4					
Ap	0-15	828	54	113	Loam sand
AB	15-54	747	76	177	Sandy loam
B	54-150	687	94	217	Sandy clay loam

Table 4: Chemical Properties of Soils of the Study Area

Horizon	Depth (cm)	pH (H_2O)	OC (g/kg)	OM	TN %	Exch. bases Na (Cmol/kg)	Ca	K	Mg	Avail. P ($mgkg^{-1}$)	Exch. Acidity Al^{3+}, H^+ (Cmol/kg)	Ext. micronutrient Mn ($mgkg^{-1}$)	Fe	Zn	Cu	Base sat. (%)	ECEC
Profile 1																	
Ap	0-17	6.06	9.9	17.2	0.7	7.0	0.23	1.7	6.33	10.0	1.9	104	47	13	75	88.93	17.16
AB	17-95	6.75	15	2.58	1.3	7.4	0.28	1.2	5.84	17.13	2.0	28	43	11	60	88.04	16.72
B	95-150	6.12	18	31	1.6	7.6	0.79	1.25	7.89	16.61	1.75	21	38	10	56	90.92	19.28
Profile 2																	
Ap	0-20	4.32	28.1	48.5	2.4	7.8	0.49	1.35	5.51	1.04	1.5	42	56	10	52	90.99	16.65
AB	20-56	4.64	33.5	57.8	2.9	7.8	0.51	1.35	4.85	4.67	1.8	18	39	10	30	88.96	16.31
B1	56-127	4.97	34.1	58.8	2.9	7.4	0.43	2.25	5.76	19.2	1.8					89.80	17.64
B2	127-180	5.04	34.1	58.8	2.9	7.9	2.61	3.29	14.8	11.42	1.3	48	46	11	55	59.30	29.90
Profile 3																	
Ap	0-28	6.45	32.9	56.7	2.8	6.2	1.02	2.45	8.06	31.66	1.4	35	43	9.0	134	92.68	19.13
AB	28-108	5.9	30.3	52.3	2.6	7.8	0.82	2.64	9.62	18.68	1.1	10	37	9.0	63	94.99	21.98
B	108-150	5.2	31.1	53.7	2.7	7.6	7.36	1.75	8.63	7.79	1.0	8	43	7.0	46	94.83	19.34
Profile 4																	
Ap	0-15	5.96	35.5	61.2	3.1	6.7	2.23	4.44	14.8	51.9	0.7	21	38	10	56	99.75	28.24
AB	15-54	5.75	30.9	53.3	2.7	7.4	0.43	2.64	9.29	5.19	1.35	142	67	10	91	93.60	21.11
B	54-150	5.65	33.7	58.1	2.9	0.6	2.17	1.4	46.46	52.42	1.85	110	48	9	38	96.47	52.18

Table 5: Summary of the land characteristics of the soil profiles for maize production

Land characteristics	Profile 1	Profile 2	Profile 3	Profile 4
Topography (t)				
Slope (%)	1.8	1.6	2	2
Climate (c)				
Rainfall during growing season (mm)	1148	1148	1148	1148
Drainage	moderate	moderate	Good	Good
Nutrient availability (0-20cm) (f)				
Total N (%)	0.07	0.24	0.28	0.31
Avail P (mg/kg)	10	1.04	31.66	51.9
Extractable K(meq/100g soil)	0.23	0.49	1.02	2.23
Mn (mg/kg)	104	142	48	35
Zn (mg/kg)	75	91	55	134
Cu (mg/kg)	13	10	11	9
Nutrient retention capacity (n)				
ECEC (meq/100g soil)	17.16	16.65	19.3	28.24
Base saturation (%)	88.93	90.99	92.68	99.75
Organic matter (%)	1.72	4.85	5.67	6.12
Soil physical characteristics(s)				
Texture	LS-SL	SCL-SL	LS	LS-SL
Soil depth(cm)	150	180	150	150

Table 6: Suitability evaluation of the soils for maize production using parametric approach

Soil	Topography(t)	Drainage	Climate (c)	Physical Properties (s)		Nutrient Avalability (f)						Nutrient retention (n)			Suitability	
Profile	Slope	(w)	Rainfall	Texture	Soil Depth	N	P	K	Mn	Zn	Cu	ECEC	OM	BS	Index	Class
1	85	95	100	85	100	60	85	85	40	40	40	100	100	95	0.72	NS_{tsf}**a**
	85	95	100	85	100	-	-	-	-	-	-	100	100	95	26.08	$S3_{ts}$ **p**
2	85	95	100	95	100	100	20	95	40	40	40	100	100	100	0.37	NS_{tf}**a**
	85	95	100	95	100	-	-	-	-	-	-	100	100	100	30.69	$S3_{t}$ **p**
3	95	100	100	85	100	100	100	100	95	40	40	100	100	100	4.91	NS_{sf}**a**
	95	100	100	85	100	-	-	-	-	-	-	100	100	100	32.3	$S3_{s}$**p**
4	95	100	100	85	100	100	100	100	95	40	95	100	100	100	11.66	NS_{sf}**a**
	95	100	100	85	100	-	-	-	-	-	-	100	100	100	32.3	$S3_{s}$**p**

Conclusion

Detailed characterization of the soils around Forestry Research Institute of Nigeria (FRIN), Ibadan showed that the soils are texturally medium, have high inherent fertility and high base status. Irrespective of the physiographic position of the soils, they were rated as being not suitable (NS) and marginally suitable (S3) or not presently suitable (NS) for the cultivation of maize. It can be recommended that the soils of the study area can be improved through agricultural practices such as use of Organic carbon amendments e.g farm yard manure or compost, use of cover crops e.g legumes (e.g., cowpea), crop rotation (legumes eg cowpea), and agroforestry and nature conservation in other to properly manage, conserve the land resources and also prevent their degradation.

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