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RESEARCH ARTICLE

SUITABILITY ASSESSMENT OF SOILS FOR MAIZE (Zea mays) PRODUCTION IN A HUMID TROPICAL AREA OF SOUTH-WESTERN NIGERIA.

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Abstract

The experiment was carried out in Akure (7^0 16^1 N, $5^0 11^1$E) , a humid zone of Southwestern Nigeria to evaluate the suitability of the soil for a long term production of maize and to have a detailed soil data base for effective land use planning. Critical nutrient requirements for maize were collected from past research work and compared with data obtained from field survey. The suitability assessment result showed that although certain qualities or characteristics such as mean annual temperature, relative humidity, topography, and base saturation were optimum for maize cultivation, there was no highly suitable (S1) land for maize cultivation in the area. Some sections in area were moderately suitable (S2). While other sections were marginally suitable (S3), the sections occupying the depressions were currently non-suitable (N1) for maize production. In order to raise the productivity level of the land to optimum performance for maize production, the management techniques should enhance the nutrient and moisture holding capacity of the soil. Such techniques should include; continuous application of organic fertilizers/materials to the soil, improved efficiency of use of mineral fertilizers and use of low levels of chemical inputs, putting up appropriate drainage facilities in place to take care of the poorly drained area of the land while provision of irrigation facilities would make dry season farming possible.

INTRODUCTION

Decisions on land use are now based on comprehensive analysis of the production and potentials of natural resources such as climate, soil, topography and hydrology. Land evaluation is very important in this direction as it provides information on the potentials and constraints for a defined land use type in terms of crop performance as affected by the physical environment. In crop production, the interest of the farmer is mainly on how profitable it is to grow a particular crop and what amendments are necessary to optimize the productivity of the soil for the specified crop (Fasina and Adeyanju, 2006). Thus, the solutions to the farmers' problems hinge on the suitability studies of the land.

Soil suitability classifications are based on knowledge of crop requirement, prevailing conditions and applied soil management methods (Ande, 2011). In other words, soil suitability classification quantifies in broad terms to what extent soil conditions match crop requirements under a defined input and management (FAO, 1970). Assessing the capability of land enables optimum performance and maximum productivity of crop. In evaluation, the specific crop requirements will be calibrated with the terrain and soil parameters (Dent and Young, 1981) so that the identified limiting factors could be managed to suit crop requirements and improve productivity.

Maize, as a major source of calories is not only humans but also for animals in Nigeria as well as other parts of the world has resulted to more soil being opened up for large scale production (Udoh and Ogunkunle, 2012). According to Esu (2004), one of the strategies to achieve food security with sustainable environment is to study soil resources to details through soil characterization and land evaluation for various land utilization types. However, in the low activity clay soils where this study was conducted, lands have been utilized intensively for different purposes at the detriment of its suitability capability thereby resulting in land degradation and imbalanced ecosystem in a landscape.

Therefore, the study was designed to assess the potentials and limitations of climatic factors and soil properties in the suitability of some selected soils of a humid South-western Nigeria for maize production.

MATERIALS AND METHODS

The study area

The study area lies between latitudes $7^0\ 16^1$ and $7^0\ 18^1$ North, and longitudes $5^0\ 9^1$and $5^0\ 11^1$ East. Topography is gently undulating and dominant slopes of between 3 and 10%. Elevation varies between 270 and 340m. Like any other part of Nigeria, Akure has a tropical humid climate characterized by high humidity (75-85%). Annual rainfall ranges between 1500 and 1800mm with temperature ranging from 21-29^{0}C. The original vegetation characteristic of the area (semi-deciduous low land rain forest) has been drastically disturbed and secondary vegetation succession like bush-regrowth, thick derived savannah has taken over the place. The type of land use is majorly arable cultivation with small sizes of maize, cassava, vegetable, oil palm and cocoa. The study area is underlain by undifferentiated basement complex materials.

Field work

An area of 16 hectares was chosen to represent the farming community. The major soil types were identified following the soil survey manual/method (Soil Survey Staff, 2003). Based on the texture, colour, soil depth, gravel content, the landscape segments were classified into five mapping units. A total of five profile pits were dug and described morphologically. Soil samples were collected for laboratory analysis.

Laboratory analysis

Soil samples were air-dried, crushed and passed through a-2mm sieve and analyzed using standard procedure. Soil particle size was determined by hydrometer method (Bouyoucos, 1962) with sodium hexameta-phosphate as the dispersing agent. Soil pH was determined by pH meter in water using a 1:1 soil/water ratio. Total N was determined by Microkjeldah method. Organic carbon was determined by the dichromate oxidation procedure (Walkley and Black, 1934). Available phosphorus was determined by the ammonium molebdate blue method (Bray and Kurtz, 1945). Exchangeable cations were determined by using 1N NH_4OAc (pH 7.0) method. Calcium and magnesium were determined by atomic absorption spectrophotometry. Exchangeable acidity was extracted with 1N KCl (Maclean, 1965). Effective cation exchange capacity (ECEC) was determined by summation of the exchangeable cations and the exchangeable acidity. Base saturation was calculated as sum of total exchangeable bases (TEB) divided by the ECEC x 100.

Land evaluation

The suitability evaluation of the land was done using the conventional method (FAO, 1970). Pedons were placed in suitability classes by matching their characteristics (Table 1 and 2) with the established requirement (Table 3). The final (aggregate) suitability class in Table 4 indicates the most limiting characteristics of the pedons. The parameters used for the land quality calculation include rainfall, mean annual temperature, slope, wetness, drainage, texture and volume of coarse while the soil materials are depth, fertility, ECEC, base saturation, organic carbon, etc as contained in Table 4.

RESULTS AND DISCUSSION

Physical properties

The upper horizons of the soils of the area have a sandy loam texture, which is sub-optimum for maize cultivation. The optimum soil texture for maize performance is clay loam or loam (Sys. 1985). The gravelly nature of pedon A poses a major limitation to maize production in the area. This is an indication that the soil is characterized by high infiltration rate and low water and nutrient retention. Thus, the ground supply may no longer be recharged through capillary action from the wetter zones at lower depth or from ground water table during dry season (Ogban and Ibia, 2006).

Chemical properties

The pH of the soil measured in water ranges from 4.5 to 6.4, indicating a very strongly to slightly acid reactions (Enwezor et al., 1989). This may be due to the acidic nature of the parent material from which the soils were derived and high rate of leaching of the nutrient down the profile. The organic carbon content of the soil is highest in the surface horizons and decreases down the profile. The organic carbon of the soil is considered moderate. The deposition of organic materials on the soil through the land use pattern (fallow) the area is subjected to would have made the soil optimum for maize production but the coarse texture of the soil (associated with high infiltration and low nutrient retention), the rate of mineralisation (due to intense cultivation) bush burning posed a major limitation.

Avoiding bush burning and continuous application of organic matter in addition to the bush fallow system will improve the aggregate stability of the soil for maize production. The available P is low and fluctuates irregularly with depth in all the pedons. This low value may be due to phosphorus fixation by the acidic nature of the soil. Exchangeable bases are generally low. The nature of the underlying parent materials, high rainfall intensity, intensity of weathering, leaching and lateral translocation of bases may have been responsible for these low values. The effective cation exchange capacity (ECEC) values that are relatively low could be attributed to the low activity clay characteristics of 1:1 clay minerals, probably dominated by Kaolinite (Lal and Stewart, 1990). The soils are generally high in base saturation (>50%) indicating that the exchange sites of the complexes (clay and humus) are dominated by basic cations.

Land suitability evaluation

The suitability classes of the soil-mapping units are shown in Table 4. The soil texture for optimum maize performance is clay loam or loam (Sys, 1985). The textural class of the soils in the area ranges between sandy loam and sandy clay loam at depth and thus cannot be highly suitable but moderately suitable (S2) for maize production.

The region is optimal or near optimal in mean annual temperature, relative humidity, length of dry season, slope and base saturation. In spite of these, none of pedons is highly suitable for maize cultivation in the area. Pedon A is gravelly-though moderate in organic carbon at 0-15 cm, it is very poor in phosphorus and exchangeable K thus, making it to be marginally suitable (S3) for maize production. The high organic carbon at 0-15 cm soil surface of pedons B and D has taken care of the low activity clay characteristics of the pedons and thus, classifies pedons B and D as moderately suitable (S2). The poor drainage condition of pedons C and E makes them currently non-suitable for maize production (N1).

Conclusion

The suitability assessment result showed that although certain qualities or characteristics such as mean annual temperature, relative humidity, topography, and base saturation were optimum for maize cultivation, there was no highly suitable (S1) land for maize cultivation in the area. The area was moderately suitable (S2), marginally suitable (S3) and currently non-suitable (N1) for maize production. In order to raise the productivity level of the land to optimum performance for maize production, the management techniques should enhance the nutrient and moisture holding capacity of the soil. Such techniques should include; continuous application of organic fertilizers/materials to the soil, improved efficiency of use of mineral fertilizers and use of low levels of chemical inputs, putting up appropriate drainage facilities in place to take care of the poorly drained area of the land while provision of irrigation facilities would make dry season farming possible.

Table 1: Particle-size distribution of soils of the study area (USDA).

Profile	Depth (cm)	**Gravel %**	**Sand %**	**Silt %**	**Clay %**	**Texture**
	0-13	16	70	18	12	SL
	13-29	16	70	12	18	SL
A	29-52	20	65	15	20	SL
	52-80	20	59	11	30	SCL
	0-20	02	70	18	12	SL
	20-38	05	67	21	12	SL
B	38-60	05	67	16	17	SL
	60-95	10	62	17	21	SCL
	95-163	10	57	22	21	SCL
	0-15	00	75	12	13	SL
	15-32	00	67	22	12	SL
C	32-61	00	67	13	20	SL
	61-82	00.	62	12	26	SCL
	82-105	00	57	17	26	SCL
	0-28	05	69	13	18	SL
	28-55	08	65	17	18	SL
D	55-72	10	60	12	28	SCL
	72-150	10	56	10	34	SC
	0-20	00	70	20	10	SL
	20-32	00	71	16	13	SL
E	32-61	00	64	18	18	SL
	61-85	00	62	14	24	SCL

Key: SL-Sandy Loam; SC-Sandy Clay; SCL-Sandy Clay Loam.

Table 2: Chemical Properties of the Soil

Profile No	Depth (cm)	pH (H_2O)	O.C %	AV.P mg/kg	Total N %	Ca ………………	K	Mg $cmolkg^{-1}$…	Na ………	E.A (H+Al)	ECEC	B.Sat. %
	0-13	5.6	1.43	7.4	0.08	1.54	0.29	0.61	0.29	0.77	3.50	78.0
A	13-29	4.7	0.86	5.3	0.04	1.64	0.29	0.48	0.22	1.38	4.01	65.6
	29-52	4.6	0.54	7.1	0.04	1.63	0.29	0.39	0.22	1.46	3.99	63.4
	52-80	4.5	0.45	10.8	0.03	1.57	0.27	0.59	0.23	1.46	4.12	64.6
	0-20	5.6	2.00	11.3	0.11	1.48	0.33	0.64	0.32	0.59	3.36	82.4
	20-38	5.4	0.46	9.5	0.02	1.59	0.34	0.57	0.32	0.80	3.62	77.9
B	38-60	5.3	0.29	5.8	0.02	1.59	0.34	0.54	0.41	1.43	4.31	66.8
	60-95	5.3	0.17	5.5	0.01	1.92	0.44	0.55	0.39	0.92	4.22	78.2
	95-163	5.1	0.15	8.6	0.01	2.01	0.42	0.66	0.24	1.68	5.01	66.5
	0-15	5.4	1.84	10.4	0.10	1.35	0.30	0.59	0.30	0.54	3.06	82.7
	15-32	4.9	0.42	8.6	0.02	1.45	0.32	0.52	0.29	0.73	3.30	77.9
C	32-61	4.9	0.27	5.3	0.01	1.45	0.31	0.49	0.37	1.31	3.93	66.7
	61-82	4.7	0.16	5.0	0.01	1.76	0.40	0.50	0.36	0.84	3.87	78.0
	82-105	4.7	0.13	7.9	0.01	1.83	0.38	0.60	0.22	1.54	4.57	66.3
	0-28	6.4	3.01	23.1	0.15	1.41	0.31	0.58	0.30	0.76	3.30	77.4
	28-55	5.4	0.62	5.7	0.03	1.49	0.31	0.50	0.18	0.96	3.44	72.1
D	55-72	5.2	0.54	8.6	0.02	1.91	0.39	0.60	0.20	0.88	3.98	77.9
	72-150	5.0	0.38	7.0	0.02	1.42	0.30	0.63	0.30	1.68	4.33	61.2
	0-20	5.4	1.95	11.0	0.10	1.44	0.31	0.62	0.31	0.57	3.25	82.5
E	20-32	5.2	0.45	9.2	0.02	1.54	0.33	0.55	0.31	0.78	3.51	77.8
	32-61	5.2	0.28	5.6	0.01	1.54	0.33	0.52	0.40	1.39	4.18	66.7
	61-85	5.0	0.17	5.3	0.01	1.87	0.43	0.53	0.38	0.90	4.11	78.1

Table 3: Land use requirement for maize.

Land Quality and Characteristics	100-95 S1	94-85 S2	84-40 S3	39-20 N1	19-0 N2
1 Climate (c):					
Annual rainfall (mm)	850-1250	850-750	750-600	600-500	-
		1250-1600	1600-1800	>1800	-
Length of dry season (days)	150-220	130-150	110-130	90-110	-
Mean annual max temp.(^{0}C)	22-26	22-18	18-16	36-30	-
		26-32	>32		
Relative humidity (%)	50-80	50-42	>80	-	-
2 Topography (t):					
Slope (%)	0-2	2-4	4-8	8-16	
	0-4	4-8	8-16	16-30	>30
3 Wetness (w)					
Flooding	F0	M0	F1	Aeric	Poor
Drainage	Good	Moderate	Poor	Poor	Drainable
4 Soil physical Characteristics (s):					
Texture/Structure	CL, L	SL, LS	LCS	CS, S	S
Coarse fragments(%) 0-10 cm	<3	3-15	15-35	35-55	-
5 Fertility (f):					
CEC (cmolkg^{-1} clay)	>24	16-24	<16(-)	16(+)	-
Base saturation (%)	>50	35-50	20-35	<20	-
pH	5.5-7.0	5.5-7.0	5.0-8.0	5.0-8.0	
OC(%) 0-15cm	>2	1.2-2	0.8-1.2	<0.8	-
Av. P (mgkg^{-1})	>22	13-22	7-13	3-7	<3
Total N (%)	>0.15	0.10-0.15	0.08-0-10	0.04-0.08	<0.08
Extr. K (cmolkg^{-1})	>0.5	0.3-0.5	0.2-0.3	0.1-0.2	<0.1

Key: F0=No Flooding; F1=Seasonal Flooding; CL=Clay Loam; SL=Sandy Loam; LS= Loamy Sand; SCL= Sandy Clay Loam; S=Sand.
Source: Modified from Sys (1985).

Table 4: Suitability class scores of the pedons in the study area.

Land Quality and Characteristics	Pedon A	Pedon B	Pedon C	Pedon D	Pedon E
1 Climate (c):					
Annual rainfall (mm)	S2 (85)	S2 (85)	S2 (85)	S2 (85)	S2 (85)
Length of dry season (days)	S1 (95)	S1 (95)	S1 (95)	S1 (95)	S1 (95)
Mean annual max temp.(^{0}C)	S1 (100)	S1 (100)	S1 (100)	S1 (100)	S1 (100)
Relative humidity (%)	S1 (100)	S1 (100)	S1 (100)	S1 (100)	S1 (100)
2 Topography (t):					
Slope (%)	S2 (85)	S2 (85)	S2 (85)	S2 (85)	S2 (85)
3 Wetness (w)					
Drainage	S1 (95)	S1 (95)	N1 (20)	S1 (95)	N1 (20)
4 Soil physical Characteristics (s):					
Texture/Structure	S2 (85)	S2 (85)	S2 (85)	S2 (85)	S2 (85)
Coarse fragments(%) 0-10 cm	S3 (80)	S1 (95)	S1 (100)	S2 (85)	S1 (100)
Soil depth	S2 (85)	S1 (100)	S1 (100)	S1 (100)	S2 (85)
5 Fertility (f):					
ECEC (cmolkg^{-1} clay)	S3 (40)	S3 (40)	S3 (40)	S3 (40)	S3 (40)
Base saturation (%)	S1 (100)	S1 (100)	S1 (100)	S1 (100)	S1 (100)
pH	S2 (85)	S2 (85)	S2 (85)	S2 (85)	S2 (85)
OC (%) 0-15cm	S2 (85)	S2 (85)	S2 (85)	S1 (95)	S2 (85)
Av. P (mgkg^{-1})	S3 (40)	S3 (60)	S3 (60)	S1 (95)	S3 (60)
Total N (%)	S3 (60)	S2 (85)	S3 (70)	S1 (95)	S2 (85)
Exch. K (cmolkg^{-1})	S3 (80)	S2 (85)	S2 (85)	S2 (85)	S2 (85)
Aggregate suitability class	**S3**	**S2**	**N1**	**S2**	**N1**
Limiting Characteristics	s, f	f	w	f	w

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