Properties and Potentials of Soils of Liman Katagum Bauchi State, Nigeria

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Abstract: ***The properties and potentials of soils of Liman Katagum (LK) in Bauchi State were assessed for both rainfed and irrigated crop production. Six soil mapping units were identified. The soils were moderately deep to very deep (93 – 163cm), except for exposed petroplinthite in some part of land unit LK 2. Soil pH ranged between 4.7 and 8.4, and was rated moderately acid to moderately alkaline. The soils were characterized by moderate fertility status. Improved management techniques were suggested for sustainable use of the land to improve farmers' economy in the area. Assessment of the land potential showed that land units LK 3, LK 5 and LK6 (47.5%; 9.975ha) were moderately suitable (S2) and LK 1 and LK 4 (27.5%; 5.775ha) marginally suitable (S3) for rainfed crop production. For irrigated crop production, land units; LK 3, LK 4, LK 5 and LK 6 (51.43%; 10.8ha) were potentially moderately suitable (S2) and Land unit LK 1 (23.57%; 4.95ha) marginally suitable (S3). Land unit LK 2 constituting 25% (5.25ha) of the land was not potentially suitable (N2) for either rainfed or irrigated agriculture.***

Keywords: Continuous cultivation, Soil management, physical and chemical properties, potential capacity.

1. Introduction

Increase in human population worldwide along with tightening economic and environmental constraints has prompted maximum crop production with resultant effect on rapid soil degradation [1] - [4]. In the midst of these challenges, agricultural productivity in the tropics and developing countries like Nigeria has been affected by ineffective and unplanned agricultural land use. For sustainable agriculture, it is necessary that every piece of land be used based on its potential capacity by appropriate allocation of lands to uses for which they are most suitable. The evaluation of land for their potential suitability can inform the farmer on the suitability and limitation of his farmland. For effective assessment of land suitability, soil information is crucial, being a major source of variation in land properties. However, this is far from reality in developing countries like Nigeria where soil information and modern agricultural inputs are grossly inadequate [1]. Hence, intensive sustainable crop production is only feasible where adequate scientific soil information is available to land users.

In spite of the importance of soils to crop production and the community dependence on land for agriculture as their major source of economy, there is dearth of information available at any scale of soil survey on the study area and their potentials are yet to be assessed. To achieve economic transformation of the farmers through sufficient food production, the study was carried out to examine the properties of the soils and assess their potential for crop production under both rained and irrigated agriculture.

2. Materials and Methods

2.1 The Study Area

The study area is situated at northern outsketch of Liman Katagum in Bauchi Local Government Area of Bauchi State, Nigeria. The site is between latitude 10° 00' 55.9" to 10° 01' 02.4" N and longitude 09° 46' 55.3" to 09° 47' 06.7" E**.** The study area is gently sloping to undulating plains. The geology is northern Nigerian basement complex rocks of the pre Cambrian age. The dominant rocks being granites, gneisses and migmatites. In the flood plain (fadama), alluvial and colluvial deposits overlie the basement complex rocks of variable thickness. The study area is within the dry sub-humid tropical high plain [5]. The mean annual rainfall of the area is 1072mm, with higher total annual potential evapotraspiration of 1200mm. The mean diurnal temperature varied between 13.1°C and 31.6°C [5], [6]. Land use of the study area involves cultivation of millet, sorghum, bambarra nut, cowpea, and groundnut during raining season. The dry season experiences low production of vegetables: okra, pepper and onion through irrigation.

2.2 Field Work

The soils were surveyed using rigid grid method at a scale of 1:2500. Traverses were made at 50m interval and auger observations were taken along each transect. Observations made were on nature and gradient of slope, slope position, vegetation, soil morphology, parent materials, erosion and land use. Soil description were done using Soil survey manual [7]. Auger points with similar soils were delineated as land unit using hand held global positioning system (GPS) and a representative profile pit dug. Six soil profile pits were dug in across the study area representing six observed mapping units. Disturbed and undisturbed soil samples were collected from genetic horizons. Steady infiltration rate of the soils were determined using double ring infiltrometers adjacent to each profile pit site.

2.3 Laboratory Analyses

The soil samples collected from the profile pits were air-dried, ground and sieved to remove materials larger than 2mm. Soil particles of less than 2mm fraction were used for the laboratory analyses. Particle size distribution was determined by hydrometer method [8]. Bulk density was determined by oven drying [9]. Total porosity was estimated from the bulk density and particle density relationship assuming particle density of 2.65Mgm^{-3}. Soil pH was determined in a 1:1 soil/water ratio and the saturation extract was also used to obtain electrical conductivity. Exchangeable bases (Ca, Mg, K, Na) were determined using NH_4OAc saturation method and exchange acidity was obtained by methods described by Thomas [10]. Cation exchange capacity (CEC) was determined by neutral (pH 7.0) NH_4OAc saturation method [11]. Base saturation and exchangeable sodium percentage (ESP) estimated by calculation, using proportion of exchangeable bases and exchangeable Na respectively to CEC in percentage. Organic carbon was determined by Walkley-Black dichromate wet oxidation method [12], total nitrogen (TN) micro-Kjeldahl technique as described by Bremner and Mulvaney [13] and available phosphorus (AP) by methods described in IITA [14] laboratory manual.

Assessment of the soils for their potential suitability for rainfed and irrigated crop production, land qualities studied were matched with irrigation and rainfed requirements for crop production [15] – [17]. Potential suitability classes were obtained from the overall ranking of the matched land qualities and crop requirement classes obtained.

3. Results and Discussion

3.1 Morphological and Physical Properties

Results of selected morphological and physical properties of soils of the study area are presented in Table 1. The soils depth ranged between 93 and 163cm, the soils varied from moderately deep (LK 2) to very deep (LK 3, 5 and 6). Petroplinthites (hardened laterites) were major constraints to depth as were observed to be exposed in some part of soil unit LK 2. Yaro et al. [18] also reported effect of petroplinthite as a constraint to plant roots development. Water table was observed in soil unit LK 4 at a depth of 143 cm. The water table was expected to rise during raining season, empairing aeration and rooting of crops. Hence, water table and its consequences have to be monitored in this soil (LK 2). Soil surface were characterized by level to slightly slope, coarse textured (gravels) surface and exposed hardened laterite due to erosion. The soils ranged from poorly drained (LK 4) to well drained (LK 6). Gravelly sandy loam and sandy clay loam texture dominated the soils.

Table 1: Morphological and Physical properties of Soils of the Study Area

Pedon	Depth (cm)	Gravel	Sand	Silt	Clay	Textural Class	Bulk Density (Mgm^{-3})	Total Porosity (%)	Steady Infiltration. Rate (mm Hr^{-1})
		(--------------	gkg^{-1}		------------)				
Pedon LK 1									
Ap	0 - 20	400	700	160	140	GSL*	1.85	30.19	118
ABc	20 – 43	400	700	180	120	GSL	1.55	41.51	
BCc	43 – 93	400	680	160	160	GSL			
C	93 – 130	400	640	120	240	GSCL			
Pedon LK 2									
A	0 - 10	400	680	180	140	GSL	1.62	38.92	62
Btc1	10 - 53	400	480	140	380	GSC	1.74	34.36	
Btc2	53 – 93	400	480	160	360	GSC			
Pedon LK 3									
A	0 - 22	0	300	360	340	CL	1.38	47.92	63
AB	22 - 31	0	200	420	380	SiCL	1.51	43.02	
B	31 – 47	0	240	360	400	CL			
BC	47 – 116	0	720	120	160	SL			
C	116-163	0	760	140	100	SL			
Pedon LK 4									
A	0 - 19	0	730	170	100	SL	1.54	41.89	44
AB	19 - 66	0	700	140	160	SL	1.53	42.26	
Bg	66 – 102	0	480	160	360	SC			
BCgw	102 - 150	0	580	100	320	SCL			
Pedon LK 5									
A	0 - 26	0	620	170	210	SCL	1.56	41.13	28
AB	26 - 53	0	530	160	310	SCL	1.66	37.35	
B	53 – 96	50	620	200	180	SL			
BC	96 - 163	150	700	160	140	SL			
Pedon LK 6									
A	0 – 15	0	740	120	140	SL	1.59	40.00	24
AB	15 – 57	0	540	100	360	SC	1.59	40.00	
B	57 – 113	0	520	160	320	SCL			
BC	113 - 157	0	560	100	340	SCL			

GSL: Gravelly sandy loam, GSCL: Gravelly sandy clay loam, GSC: Gravelly sandy clay, SL: Sandy loam, SC: Sandy clay, SCL: Sandy clay loam

Bulk density ranged between 1.28 and 1.85 Mg m^{-3} in the soils. Soil total porosity varied between 30.19 and 51.70%. Bulk density values from 1.7 to 1.8 and 1.45 to 1.65 Mg m^{-3} for sandy and clayey soils have been reported to inhibit root growth [19], [20]. Hence soils with high bulk density will inhibit root growth due to soil's resistance to root penetration, poor aeration, slow movement of nutrients and water, and build up of toxic gases and root exudates [2], [21], [22]. Soils of land units LK 1 and LK 2 will require more and deep tillage to reduce compaction effects and provide conducive environment for crop growth. The bulk densities and total pore space values of the soils were rated moderate and were considered to favour good aeration, root penetration and free water movement in the soils, except LK 1 and LK 2 tend to be high. The range of the steady infiltration rates was between 24 and 118 mm/hour, and was rated moderate to very high.

The data related to chemical properties are presented in Table 2. The values of soils pH varied between 4.7 and 8.4 indicating very strongly acid to moderately alkaline reaction [23]. Electrical conductivity varied between 0.04 and 0.70 dSm^{-1} in the soils. The electrical conductivities of the soils were below the critical limit of 4 dSm^{-1} needed to define a saline soil [2], [7].

3.2 Chemical Properties

Table 2: Chemical Properties of Soils of the Study Area

Pedon	Basal Depth (cm)	pH	Exchangeable Bases Ca	Mg	K	Na	EA	CEC	PBS	OC	TN	AP	ESP	ECe
			(----------------cmol (+) kg^{-1}					--------------------)	(%)	gkg^{-1}	gkg^{-1}	$mgkg^{-1}$	%	dSm^{-1}
Ap	20	7.7	2.6	1.0	0.48	0.16	0.05	9.6	44.2	6.4	0.35	16.62	1.67	0.18
ABc	43	7.5	6.2	2.2	0.41	0.17	0.05	16	56.1	5.7	0.70	7.77	1.06	0.14
BCc	93	7.0	5.8	2.0	0.23	0.09	0.05	9.4	90.2	1.3	0.70	34.44	1.96	0.09
C	130	8.4	4.4	1.8	0.39	0.17	0.05	7.6	88.9	0.2	0.35	7.00	2.24	0.04
Pedon LK 2														
A	10	8.3	1.6	0.8	0.28	0.15	0.05	7.8	36.3	5.9	0.35	0.64	1.92	0.08
Btc1	53	8.2	3.4	1.4	1.30	0.70	0.05	9.0	75.6	0.9	0.35	0.48	7.29	0.05
Btc2	93	7.8	1.4	0.8	0.17	0.12	0.05	9.6	28.0	2.4	0.70	0.54	1.25	0.08
Pedon LK 3														
A	22	5.8	3.2	1.4	0.22	0.13	0.10	12.6	49.0	14.7	1.05	6.61	1.03	0.07
AB	31	6.2	3.6	1.6	0.32	0.24	0.10	12.6	45.7	10.1	1.05	8.61	1.90	0.09
B	47	5.9	3.8	1.2	0.32	0.21	0.10	13.6	40.7	10.3	0.70	7.00	1.54	0.70
BC	116	5.9	3.4	1.2	0.47	0.34	0.10	13.8	39.2	8.1	0.70	6.61	2.46	0.06
C	163	5.8	0.6	0.4	0.15	0.03	0.10	7.20	16.4	1.5	0.35	1.94	0.42	0.07
Pedon LK 4														
A	19	5.7	2.0	0.8	0.90	0.30	0.10	4.2	88.8	3.0	0.35	1.28	7.14	0.08
AB	66	6.0	1.0	0.6	0.09	0.21	0.10	4.0	47.5	0.1	0.70	1.21	5.25	0.05
Bg	102	6.2	2.2	0.8	0.16	0.22	0.10	9.6	35.2	0.2	0.70	0.64	2.29	0.04
BCgw	150	6.3	2.2	1.0	0.97	0.40	0.10	8.8	51.9	0.1	0.35	0.34	4.54	0.05
Pedon LK 5														
A	26	5.8	1.3	0.7	0.35	0.25	0.30	4.3	60.5	14.7	1.05	0.54	5.81	0.35
AB	53	5.3	2.6	1.2	0.25	0.35	0.20	6.4	68.8	10.3	0.70	0.57	5.47	0.30
B	96	5.6	1.6	0.8	0.37	0.31	0.10	4.7	65.5	1.9	0.70	0.43	6.60	0.08
BC	163	5.4	1.3	1.0	0.27	0.32	0.10	5.3	54.5	0.8	0.35	5.47	6.04	0.06
Pedon LK 6														
A	15	5.1	1.2	0.6	0.25	0.30	0.40	5.8	40.5	1.7	0.70	0.64	5.17	0.45
AB	57	5.2	1.2	0.6	0.05	0.32	0.20	5.4	40.2	7.0	0.35	0.60	5.93	0.40
B	113	5.5	1.4	0.8	0.26	0.28	0.10	4.0	75.5	1.0	0.70	0.57	7.00	0.35
BC	157	5.8	2.4	1.0	0.39	0.96	0.10	5.6	84.8	0.1	0.70	0.48	17.00	0.30

Calcium was the principal saturating cation in all the soils with a values ranging from 0.60 to 6.20 cmol (+) kg^{-1} in the soil. Magnesium, potassium and sodium ranged between 0.40 and 2.20, 0.05 and 1.30 and 0.03 and 0.96 cmol (+) kg^{-1} respectively in the soils. The contents of Ca, K and Na were rated low to high and Mg was medium to [23], [24]. The present bases status showed that the soils have not loss most of their bases through leaching, however fertilizers containing these elements will be required to be applied timely in low to medium quantity and by burying to remedy the deficiency in crops. Cation exchange capacity (CEC) values varied between 4.0 and 16.0 were less than 12 cmol (+) kg^{-1} in the soils and were rated low to high. The dominant medium CEC of the soils may be an indication that the soils have not undergone advance weathering.

Incorporation of organic matter and addition of bases under fertilizer programme would raise CEC of these soils [2], [25] as management suggestions for sustainable use of the land. Exchange acidity ranged between 0.05 and 0.4 cmol(+)kg^{-1} in the soils and was rated low, indicating loss of bases by leaching have not occurred significantly to warrant their replacement by exchange acid. This is strongly affirmed by the near neutral to alkaline pH of the soils. Base saturation values ranged between 28.00 and 90.20% and rated low to high in the soils.

The content of organic carbon, total nitrogen and available phosphorus ranged from 0.10 to 14.70 gkg^{-1}, 0.35 to 1.05 gkg^{-1} and 0.43 to 34.44 $mgkg^{-1}$. Organic carbon content was rated low to medium, total nitrogen was low and available phosphorus was low to high [23], [24]. For sustainable crop production, organic manure and fertilizers (N, P and K) addition in adequate quantity and preferably buried at a shallow depth adjacent to plant roots were recommended.

3.3 Soil Potential Suitability for crop Production

The potential suitability classes for both rainfed and irrigated crop production are presented in Table 3. Land mapping units obtained from soil survey and soil properties determinations are presented in Figure 1.

Table 3: Land Unit Potential Suitability Classes for Crop production

Land Unit	Land Area (ha)	Land Area (%)	Rainfed Suitability Class	Irrigation Suitability Class
LK 1	4.950	23.57	S3sd	S3sd
LK 2	5.250	25.00	N2	N2
LK 3	2.250	10.71	S2st	S2st
LK 4	0.825	3.94	S3sdw	S2sd
LK 5	6.000	28.57	S2st	S2st
LK 6	1.725	8.21	S2st	S2st
Total	21.000	100.00		

S2 = moderately suitable, S3 = marginal suitable, N2 permanently not suitable, s = soil condition, t= topography, d = drainage, w = water table.

Assessment of the soils showed that none was highly suitable currently for either rainfed or irrigated crop production due to the fertility status, drainage and slope condition of the soils. Land units LK 3, LK 5 and LK 6 were ranked moderately suitable (S2) for rainfed and constitute 47.5% (9.975ha) of the study area, whereas land units LK 3, LK 4, LK 5 and LK 6 were ranked moderately suitable (S2) for irrigated agriculture and constitute 23.57% (4.95ha) of the farm land. The soils were rated moderately suitable due to the medium fertility soil conditions, slight slope contributing to erosion and poor drainage in LK 4. Land unit LK 4 (3.93%; 0.825ha) was ranked marginally suitable (S3) for rainfed cropping due to moderate fertility, poor drainage and expected high water table in raining seasons. The udic (longer) soil moisture regime allowed its ranking as moderately suitable for (S2) for rice and sugar cane production. Land unit LK 1 (23.57%; 4.95ha) was ranked marginally suitable (S3) for both rainfed irrigated cropping due to low fertility, poor drainage and gravels. However, the soil (LK 1) was considered moderately suitable for bambara nut being a shallow rooted crop that strive in poor soils and it is a crop produce for it economic purpose in the area. Land unit LK 2 (5.25ha) constitute 25% of the total area was not suitable permanently (N2), both for rainfed and irrigated cropping due to low fertility status, poor drainage, exposed hardened laterite and slightly steep slope causing erosion. The sub-class features (symbols) indicated critical factors affecting suitability of the soils for crop production under rainfed or irrigation that require management practice for sustainable use of the land and improving farmers economy.

4. Conclusions

The soils in the study area were found to be moderately deep to very deep (93 – 163cm). Soil pH ranged between 4.7 and 8.4, and was rated moderately acid to moderately alkaline. The soils were characterized by moderate fertility status as exchangeable bases were not highly loss through leaching and base saturations were mostly medium to high. However, there is still need for improved management techniques for the sustainable use of the land to improve farmers' economy in the area. Assessment of the land potential showed that 47.5% (9.975ha) of the soils were moderately suitable (S2), 27.5% (5.775ha) marginally suitable (S3) and 25% (5.25ha) not suitable (N2) for rainfed crop production. For irrigated crop production, 51.43% (10.8ha) of the soils were potentially moderately suitable (S2), 23.57% (4.95ha) marginally suitable (S3) and 25% (5.25ha) not suitable (N2).

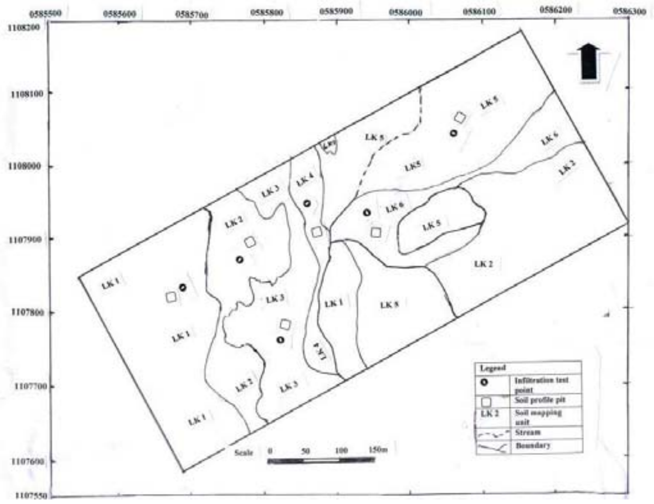

Figure 1: Soil Mapping Units of the study area

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