

SOIL SURVEY AND LAND SUITABILITY EVALUATION FOR SUGAR CANE PRODUCTION AT ZAGGA DISTRICT, BAGUDO LOCAL GOVERNMENT AREA, KEBBI STATE, NIGERIA.

ABSTRACT

Semi-detail soil survey and land suitability evaluation for sugarcane production was carried out in Zagga, Bagudo LGA of Kebbi State Nigeria at scale of 1:25,000 on 8,000 ha of land. The objectives were to describe the morphological and chemical properties of the soils. The entire study area was classified into five soil units named as ZG1, ZG2, ZG3, ZG4, and ZG5. Surface soil samples were examined and collected from 0-15cm, 15-30cm depth using soil auger at 200x200m interval. Five soil profile pits were dug, described and soils sampled from bottom up, to minimize contamination by falling debris. Each soil profile pit was described based on horizon thickness, depth, colour of matrix and mottles, consistency, included materials, roots, horizon boundary, vegetation/ land use, slope, depth to water table and drainage status. The soils are slightly acidic (6.30) to moderately acidic (5.60). The total nitrogen, organic carbon, available phosphorus, and basic cations (Ca, Mg, K, Na) were low to moderately low according to guidelines for nutrient rating and interpretation for Nigerian soils. The soils were moderately drained. According to USDA soil taxonomy classification the soils of ZG 1 and ZG 2 were classified as *Dystrustepts* while ZG 3, ZG 4 and ZG 5 were classified as *Haplustepts* and correlated with World Reference Based System as *Arenosols* and *Luviosols*. ZG1 and ZG2 were named as moderately suitable (S2) while ZG3, ZG4 and ZG5 were marginally suitable (S3) according to the guidelines of land suitability evaluation for sugarcane production.

Keywords: *Soil survey, Land Suitability, for Sugarcane and Production*

INTRODUCTION

Soil survey is the systematic study of the soils of an area including classification and mapping of the properties and the distribution of various soil units. Systematic soil survey has been carried out for over hundred years. As in other applied sciences, conceptual and technological advances are making soil survey more reliable, cheaper and useful (Brady and Weil, 1996). The practical purpose of soil survey is to enable more numerous, more accurate and more useful predictions to be made for specific purposes than could have been made otherwise (FOA, 1997).

Land suitability is the fitness of a given type of land for a defined use which could be considered in its present condition or after improvements. The process of land suitability classification is the appraisal and grouping of specific areas of land in terms of their suitability for defined uses.

Land evaluation is a process of predicting land performance over time according to the specific types of use (Zonneveld, 1989, Rossiter, 1996, Lee and Yeh, 2009, Martin and Saha, 2009).

Agriculture land suitability assessment is defined as the process of assessment of land performance when used for alternative kinds of agriculture (He *et al.*, 2011, Mu, 2006, Prakash, 2003). Over the past three decades there have been changes in land use, which promoted continuous cultivation of soil around savanna areas for grains and vegetables for commercial benefits. Continuous cultivation may increase or decrease oxygen supply to the soil and could exert influence on soil organic matter and vital soil processes (Brady and Weil, 2002). The direction and the magnitude of the changes in soil characterization, physical and chemical behavior in cropped fields have not been adequately ascertained in the study area. If farmers are made to understand the properties of their soils, better utilization and management strategies and implementation of improved technologies as well as increased yield of crops is expected. It may also reduce the damage to land and ecosystems (Malami *et al.*, 2011). Soil analysis and characterization allows for grouping of soils into various classes, such as very low, low, medium and high according to their various properties in the soils. It also helps to predict the probability of getting a profitable response to fertilizer, amendments application and evaluation of soil fertility status. Farmers rarely have adequate information regarding their soils in some localities within Nigeria (Hassan *et al.*, 2013).

MATERIALS AND METHODS

Location of the Study Area

The study was conducted on a Fadama land in Zagga District Bagudo Local Government area of Kebbi State. Bagudo town lies on latitude (10-12°06N and Longitude 3-4°10E) in Sudan savanna zone of Nigeria. The climate of the area is typical of tropical climate, characterized by wet and dry seasons. The dry season is usually 7 months in most cases from November to May while the rainy season last for 4-5 months usually from June to October. The area experiences an average annual rainfall of 500 to 650mm with relative humidity in the range of 21- 47% during dry season which increase more than 51% in the wet season. Average annual temperature ranged from 25-45 in the study area (Anon, 2009).

Field Study

Semi-detail soil survey at the scale of 1:25,000 was conducted on 8,000ha of land in Zagga District of Bagudo Local Government Area of Kebbi State. This involved establishing a baseline followed by soil augering along transects to identify soil types and their boundaries. However, Visual Soil Assessment (VSA) was conducted in order to assess and evaluate the land suitability of soils in the study area. In each soil mapping unit that was identified, a soil profile pit was dug and described followed by sampling from the bottom up to minimized contamination by falling debris. Each pit was described based on morphological characteristics according to established standard procedure (FAO, 2006, Soil Survey Staff, 2012). The characteristics described include, soil depth, horizon thickness, color of matrix and mottles, texture, structure, consistence, porosity, included materials, roots and horizon boundary, records of vegetation/land use, topography, slope, depth to water table and internal drainage status. However, following the descriptions, soil samples (disturbed and bulk) were collected from each genetic horizon for laboratory analysis. The entire study area was subdivided in to five soil units named a ZG1, ZG2, ZG3, ZG4, and ZG5.

Soil Sampling

Surface soil sampling as well as profile study and description was carried out for soil analysis and classified soil. Surface sample collection in the field was done at a distance of 200x200m interval throughout the survey process in the study area.

Laboratory Methods

The samples were air-dried, carefully crushed using a wooden and pestle and then sieved through a 2mm mesh. The sieved samples were stored for physical and chemical analyses. Particle size analysis was determined using the hydrometer method (Bouyoucos, 1962) with sodium hexameta-phosphate as the dispersing agent. Bulk density was determined by the use of core

sampler method (Blake and Harge, 1986). Particle density was determined by the use of pycnometer bottle method (Blake, 1965). Total porosity was calculated from particle and bulk densities using the relationship $p=100(1-Bd/Pd)$, where p = porosity, Bd = Bulk density, Pd = Particle density and 100 and 1 are constants. Soil pH (1:1) in H_2O and $CaCl_2$ were determined using glass electrode pH meter (Adesonwo *et al*, (2013). Organic carbon content of the soils was determined by the acid-dichromate oxidation method of Walkley-Black (1934). Total N was determined by digestion and distillation method using micro Kjeldahl technique (Nottidge, 2011). Available P was determined following the procedure described by IITA (1979) using Bray-1 extraction method (Bray and Kurtz, 1945). Exchangeable bases (Ca, Mg, K and Na) in the soil were extracted with 1.0m ammonium acetate (NH_4OAc) extracting solution buffered at pH_7 . Exchangeable Ca and Mg were determined by EDTA titration (Ahukaemere *et al*, 2014). Exchangeable K and Na was determined using flame photometer. Electrical conductivity was measured using electrical conductivity meter (Simon, 2000). The CEC was determined by neutral ammonium acetate method buffered at $pH 7$ (Rhoades, 1982). The exchangeable sodium percentage was calculated as proportion of CEC (NH_4OAC) occupied by sodium cations as follows: $ESP = \frac{Exch.sodium}{CEC(NH_4OAC)} \times 100$. Soils were classified using USDA Soil Taxonomy classification and were correlated with the World Reference Base for Soil Resources. The data was analyzed using descriptive statistics such as means and weighted averages.

RESULTS AND DISCUSSION

The morphological, physical, chemical and taxonomic classifications of the soils are presented in Tables 1, 2, and 3 respectively.

Table 1. Morphological properties of the soils

Horizon	Depth (cm)	Munsell color(moist)	Textur e	Structur e	Mottling	Consistenc y (moist)	Root	Horizon Boundar y
ZG1								
(Haplustepts)								
Ap	0-16	10YR5/2	LS	ABK	7.5YR5/ 4	H	MR	SD
Btg1	16-33	10YR5/1	SL	PLY	7.5YR4/ 4	SH	MMR	SD
Btg2	33-55	10YR3/3	SL	SABK	7.5YR3/ 4	SH &FR	MMR	SD
Bc	55-75	10YR4/3	LS	SABK	-	SH	VFW R	SD
ZG2								
(Haplustepts)								
Ap	0-22	10YR3/4	LS	ABK	10YR6/7	H	MR	D
ABg1	22-32	10YR3/3	SL	ABK	10YR6/6	FR	MR	D
ABg2	32-49	10YR5/2	LS	Platy	10YR6/6	SH	VFR	D
Btg1	49-91	10YR6/2	SL	SABK	10YR6/6	EH	VFR	D
Bcg	91-150	10YR7/1	LS	ABK	10YR7/6	FR	FWR	
ZG3								
(Haplustalfs)								
Ap	0-19	7.5YR6/2	LS	SABK	7.5YR6/ 3	V.FR	MMR	D
AB1	19-59	7.5YR5/2	LS	ABK	-	V.FR	VFR	D
AB2	59-91	7.5YR5/2	LS	ABK	-	FR	NR	D
ABg	91-141	10YR6/3	LS	SABK	7.5YR5/	V.H	NR	D

Bc	14120	10YR6/7	LS	ABK	-	FR	NR	D
	0							

ZG4

(Haplustalfs

)

Ap	0-16	10YR5/3	LS	ABK	10YR7/6	L	MFR	D
AB	16-33	10YR6/4	LS	ABK	-	L	MFR	D
Bc	33-71	10YR6/3	LS	MSV	-	L	MR	D

ZG5

(Haplustalfs

)

Ap	0-13	10YR3/4	LS	ABK	10YR5/7	FR	MR	D
Bt1	13-29	10YR5/1	LS	ABK	-	V.H	NR	D
Bt2	29-53	10YR5/2	LS	Platy	-	FR	FR	D
Bt3	53+	10YR4/2	S	ABK	-	L	NR	D

S= sand, LS= loamy sand, SL= sandy loam, ABK = Angular Blocky, PLT = Platy, SABK = Sub-Angular Blocky, M = Massive, 10YR5/2 = yellowish brown, 7.5YR5/2 = Dull brown, 10YR7/1 = Bright brown, 7.5YR6/2 = Orange, 7.5YR3/4 = Dark brown, 10YR6/7 = Bright Reddish brown, 10YR4/3 = Dark Reddish brown, 10YR³/₃ = Dark Yellowish, 10YR⁵/₁ Dark Grey brown, 10YR⁷/₁ = 10YR⁶/₃ = Dark Yellowish, 10YR⁴/₂ = Light Brown, 10YR⁵/₃ = Light Grey Brown, H = hard, VH, SH&FR = Slight Hard and Friable, SH = Slight Hard, FR= Friable, VFR = Very Friable, L = Loose, EH = Extremely Hard, MR= Medium Roots, MMR = Many Medium Roots, MFR = Many Fine Roots, VFR = Very Fine Roots, NR = No Roots. FWR = Few Roots, VFWR = Very Few Roots, SD = Slight Diffuse, D = diffus

Soil morphological characteristics

The morphological properties of the soils are presented in Table 1. The soil of all the pedons are generally deep with depth of >50cm. The colour of the soil varied from dark Grey (10YR⁵/₂) in the surface horizon changing to bright (10YR⁷/₁) in the subsurface horizon. The texture of the soil varied from loamy sand to sandy loam in the surface horizon changing to loamy sand in the subsurface horizon with strong medium angular blocky structure in the surface horizon changing to moderate medium sub-angular blocky structure in the subsurface horizon. Similar result was found by Eshett, (2003). The consistence of the soil varied from hard to very hard, firm and sticky-plastic to very sticky-plastic. The clay content increased with depth which indicates the presence of argillic horizon. The root of the soils varied from many roots changing to medium roots in the surface horizon and very few roots in the subsurface horizons.

Table 2. Chemical Properties of the Soils

Horizon	Depth (cm)	pH (water)	EC dsm-1	OC gkg-1	OM	TN	AP mgkg-1	Ca cmolkg-1	Mg	K	Na	CEC	ESP %
ZG1 Haplustepts													
Ap	0-16	6.50	0.055	6.60	11.38	0.70	2.92	3.60	0.80	0.07	0.04	5.80	0.69
Btg1	16-33	6.10	0.025	4.40	7.59	0.35	2.57	3.00	0.78	0.09	0.42	5.20	8.08
Btg2	33-55	5.70	0.005	5.80	10.00	0.35	2.70	3.60	0.97	0.24	0.35	6.00	5.83
BC	55-75	5.80	0.009	3.71	6.40	0.07	2.40	2.40	0.65	0.19	0.45	5.00	9.00
	Mean	6.03	0.024	5.13	8.84	0.37	2.65	3.15	0.80	0.15	0.32	5.50	5.73
ZG2 Haplustepts													
Ap	0-22	6.70	0.008	6.30	10.86	0.80	3.12	3.80	1.12	0.10	0.05	6.70	0.75
ABg1	22-32	6.00	0.0048	4.80	8.28	0.46	2.84	3.50	0.92	0.08	0.40	5.90	6.78
ABg2	32-48	5.90	0.008	5.30	9.14	0.41	2.65	2.90	0.83	0.15	0.43	5.70	7.54
Btg1	48-81	5.80	0.006	5.70	9.83	0.28	2.33	3.40	0.99	0.18	0.83	6.40	12.97
BCg	81-150	5.80	0.0059	3.20	5.52	0.22	2.36	2.90	0.72	0.13	0.71	5.81	12.22
	Mean	6.04	0.00654	5.06	8.72	0.43	2.66	3.30	0.92	0.13	0.48	6.10	7.93
ZG3 Haplustalfs													
Ap	0-18	5.80	0.046	7.00	12.07	0.83	2.72	3.28	0.98	0.23	0.07	5.90	1.19
AB1	18-59	6.10	0.014	5.45	9.40	0.56	2.98	3.09	0.78	0.15	0.33	5.67	5.82
AB2	59-91	6.30	0.015	5.32	9.17	0.44	2.63	2.95	0.88	0.12	0.37	5.61	6.60
ABg	91-141	5.80	0.022	5.55	9.57	0.31	2.41	2.68	0.91	0.26	0.29	5.34	5.43
BC	141-200	5.90	0.013	3.05	5.26	0.09	2.64	2.31	0.6	0.18	0.44	5.16	8.53
	Mean	5.98	0.022	5.27	9.09	0.45	2.68	2.86	0.84	0.19	0.30	5.54	5.42
ZG4 Haplustalfs													
Ap	0-16	6.50	0.005	6.33	10.91	0.67	3.10	2.81	1.20	0.34	0.65	6.20	10.48
AB	16-33	5.60	0.006	4.45	7.67	0.43	2.60	2.31	0.93	0.29	0.41	5.60	7.32
BC	33-71	5.70	0.006	3.32	5.72	0.36	2.00	2.11	0.87	0.26	0.53	4.90	10.82
	Mean	5.93	0.006	4.70	8.10	0.49	2.57	2.41	1.00	0.30	0.53	5.57	9.52
ZG5 Haplustalfs													
Ap	0-13	6.20	0.131	5.86	10.10	0.64	2.81	3.41	0.98	0.41	0.50	6.90	7.25
Bt1	13-28	6.00	0.052	5.09	8.78	0.51	2.39	2.94	0.91	0.33	0.40	5.70	7.02
Bt2	28-53	5.80	0.044	4.16	7.17	0.38	2.13	2.70	0.83	0.30	0.35	5.30	6.60
Bt3	53+	5.60	0.028	3.22	5.55	0.31	2.04	2.15	0.69	0.21	0.45	5.10	8.82
	Mean	5.90	0.06375	4.58	7.90	0.46	2.34	2.80	0.85	0.31	0.43	5.75	7.39

AP= Available Phosphorus, Ca= Calcium, Mg= Magnesium, K= Potassium, Na= Sodium, CEC= Cation Exchange Capacity, ESP= Exchangeable Sodium Percentage

Chemical Properties of the Soils

The pH of the soils is presented in Table 3. The pH values in all the pedon fall within moderately acidic range (5.93 – 6.50). The moderately acidic pH values of the soils could be attributed to downward movement of the basic cation along the slope. Similar result has reported by Jamala and Oke (2013) in the study of the soils of Northeast Nigeria. The EC of the soil is presented in Table 3. The EC values in all the pedons fall within moderately low (0.006dsm^{-1} - 0.024dsm^{-1}) indicating non-saline status of the soil. Similar result was reported by Dohnke and Whitney, (2006). The OC and OM of the soil is presented in Table 3. The OC and OM values in all the pedons fall within very low range (4.57g/kg – 5.27g/kg) and (7.90g/kg – 9.09g/kg) respectively. The very low organic carbon values of the soils could be attributed to continuous cultivation and frequent burning of residues. This finding agreed with finding of Suharta and Prasetyo (2007) in the study of soil of Riau. The TN, AvP, and K values of the soils are presented in Table 3. The mean values of nitrogen at ZG1, ZG2, ZG3, ZG4, and ZG5 were 0.37g/kg, 0.43g/kg, 0.45g/kg, 0.49g/kg and 0.46g/kg respectively. The TN, AvP, Ca, Mg, and Na values in all the pedons fall within low ranged (0.37g/kg – 0.49g/kg), (2.34mg/kg – 2.69mg/kg), (2.41cmol/kg – 3.30cmol/kg), (0.72cmol/kg to 1.00cmol/kg) and (0.04cmol/kg to 0.65cmol/kg) respectively. The low TN, AvP, Ca, Mg, and Na of the soils could be attributed to continuous cultivation and leaching (Yakubu *et al*, 2011). Similar result was reported by (Ekwoanya and Ojanuga, 2002; Singh *et al*; 2001; and Adepetu, 1979). The exchangeable potassium is presented in Table 3. The exchangeable potassium values in all the pedons fall within moderately high range (0.13cmol/kg – 0.31cmol/kg). The moderately high potassium values of the soil could be attributed to high Mg element in the soil which caused K deficiency in plant and soil with high Mg tends to have poor structure as primarily reported by Noma *et al* (2004) in the study of the soil of Sokoto State. The CEC values in all the pedons fall within low to moderate range (5.50cmol/kg – 6.90cmol/kg). This finding has agreed with finding of Yakubu *et al* (2006). The ESP values in all the pedons fall within very low percentage range (4.41% - 9.52%). The very low ESP values could be attributed to dominance of other basic cations in the soil (Brady and Weil, 2002) in the study of sodic soils. Similar result was obtained by (Sanda *et al*; 2007).

Table 3. Taxonomic classification of the soils

	PEDON	Soil Series	USDA SYSTEM	FAO/UNESCO LEGEND (WRB)
1	<i>ZG1</i>	<i>Kwasara Series</i>	<i>Haplustepts</i>	<i>Arenosols Stagnic (loamic)</i>
2	<i>ZG2</i>	<i>Kohel Series</i>	<i>Haplustepts</i>	<i>Arenosols Stagnic (loamic)</i>
3	<i>ZG3</i>	<i>Mado Series</i>	<i>Haplustalfs</i>	<i>Haplic Luvisols</i>
4	<i>ZG4</i>	<i>Manga Series</i>	<i>Haplustalfs</i>	<i>Haplic Luvisols</i>
5	<i>ZG5</i>	<i>Gucuware Series</i>	<i>Haplustalfs</i>	<i>Haplic Luvisols</i>

Taxonomic classification of the soils

The soils were classified according to the USDA Soil Taxonomy System (USDA 2014) and correlated with the FAO/UNESCO Legend of the World Reference Based (WRB) System (FAO/ISSS, 2006). These two systems are the most commonly used ones in Nigeria for soil classification. The five soils mapping units that were identified in the study area were designated ZG1, ZG2, ZG3, ZG4, and ZG5. The soils of ZG1 and ZG2 were classified as *Haplustepts* at great group for having ground water commonly fluctuates from a level near the soil surface to below a depth of 200 cm while the soils of ZG3, ZG4 and ZG5 were classified as *Haplustalfs* because they do not have a natric or kandic horizon (Soil Survey Staff, 1999; 2014) and correlate with World Reference Base (WRB) as *Arenosols* for having texture class of loamy sand and *Luvisols* for having argillic horizons overlain by loamy sand.

Land Suitability Classes in the Study Area

Land suitability is usually evaluated using parameters, such as rainfall, texture, drainage, soil depth, slope, pH, erosion hazard, risk of flooding and accessibility. The basic land quality groups in suitability determination of soil for sugarcane production were climate, topography, soil physical and chemical properties (Sys *et al*; 1993). Based on the general low fertility levels of

the soils organic materials (plants and animals residues) should be applied substantially to improve fertility levels of the soils Udoh *et al* (2011). The standard criteria used for sugarcane suitability is presented in Table 4. The FAO Land suitability guidelines in which land has been classified as highly suitable (S_1), moderately suitable (S_2), marginally suitable (S_3), currently unsuitable (N_1), and permanently unsuitable (N_2) has been adopted. Land quality and factors rating of soil suitability classes for sugarcane production was presented in Table 2, and Table 3. Soil suitability ranged from moderately suitable (S_2) in ZG 1, 2 and marginally suitable (S_3) in ZG 3, 4 and 5.

Conclusion

The physical properties of the soils indicated a relatively high bulk density, particle density and low porosity. The soil pH was slightly acidic, content of organic carbon, organic matter, total nitrogen, available phosphorus, exchangeable potassium, basic cation (Ca, Mg, K, Na), exchangeable sodium were low. The soils tend to have low water holding capacity and low cation exchange capacities but are easy to cultivate. According to USDA soil taxonomy system, two soil units were identified as ZG1 and ZG2 (Dystrustepts), ZG3, ZG4 and ZG5 (Haplustepts) and correlate with World Reference Base (WRB) as Arenosols and Luvisols. The soils of ZG1 and ZG2 were moderately suitable (S_2) while soils of ZG3, ZG4 and ZG5 were marginally suitable (S_3) for sugarcane production based on FAO (1983) guidelines.

Recommendations

- 1 The limiting factors of land suitability of the soils of Zagga Districts for sugarcane cultivation were low available P, exchangeable K, CEC and TN, therefore organic materials (plants and animals residues) should be applied substantially to improve fertility levels of the soils.
- 2 Liming also should be carry out going by the acidic nature of the soils to improve their conditions.

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Figure 1 & 2 : Picture of study sample collection

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