SOIL SURVEY AND LAND SUITABILITY EVALUATION FOR SUGARCANE PRODUCTION ON CHEMICAL PROPERTIES IN 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 in to 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 minimized 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 *Luvisols*. 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, Chemical, 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).

MATERIALS AND METHODS

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.

Laboratory Methods

The samples were air-dried, carefully crushed using a wooden and pestle and then sieved though 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_20 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= $\frac{Exch.sodium}{CEC(NH4OAC)} \times 100$. 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, 3 and 4 respectively.

Table 1. Morphological properties of the soils

Horizon	Depth (cm)	Munsell color(moist)	Texture	Structure	Mottling	Consistency (moist)	Root	Horizon Boundary
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	VFWR	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

					7			
Bc	141200	10YR6/7	LS	ABK	-	FR	NR	D
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, 10YR$^{3}/_{3}$ = Dark Yellowish, 10YR$^{5}/_{1}$ Dark Grey brown, 10YR$^{7}/_{1}$ = 10YR$^{6}/_{3}$ = Dark Yellowish, 10YR$^{4}/_{2}$ = Light Brown, 10YR$^{5}/_{3}$ = 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 (10YR$^{5}/_{2}$) in the surface horizon changing to bright (10YR$^{7}/_{1}$) 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 3. 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), (0.72cmlo/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 4. Taxonomic classification of the soils

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

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 ZGI, 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 4.2, and Table 4.3. Soil suitability ranged from moderately suitable (S_2) in ZG 1, 2 and marginally suitable (S3) 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 (S2) while soils of ZG3, ZG4 and ZG5 were marginally suitable (S3) for sugarcane production based on FAO (1983) guidelines.

References

Adepetu, J.A . (1979) . A Preliminary Survey of fertility status of some soils in Ondo State, under traditional cultivation. *Ife Journal of Agriculture* 1: 134-149.

Adesanwo,O.O., A.A.Lasisi and O.B. Otewande (2013). Phosphorus availability from thermally Phosphate rock. *Negerian Journal of soil science 23 (1) ; 63-73.*

Ahukaemere, C.M.,E.Tshett and C. Ahiwe (2014). Characterization and fertility status of wetland soils in Abia State agro ecological zone of southeastern Nigeria. Nigerian Journal of soil science 24 (10): 147-157

Blake, G.R. and Hartge, K.H. (1986) Bulk density. In: Klute, A., Ed., *Methods of Soil Analysis, Part 1—Physical and Mineralogical Methods*, *2nd Edition*, *Agronomy Monograph 9*, American Society of Agronomy—Soil Science Society of America, Madison, 363-382.

Bouyoucos, G.J. (1962). A recalibration of the hydrometer method for making mechanical analysis of soils. *Agronomy Journal*, 43: 434-43

Brady, N.C. and Weil, R.R. (1996).*Methods of soil analysis*.Part 2. ASA, 677 SegoeRd S, Madison, WI 53711.

Dahnke, W.C and D.A. Whitney (2006). Measurement of Soil Salinity, P. 32-34. In recommendation Soil chemical test procedure for the North CentralRegion, NCR Publ.221:

Dikko, A.U, I. Ahmed, I. Ado and S.S. Noma (2011). Organic carbon, Totalnitrogen, andavailable P distribution the soil particles, GIdanJaja Grazing Reserved, Zamfara state, Nigeria. *Best Journal* (2): 64-69

Elsheik E.T (2010) A.R. Elsheik, N. Ahmad, A. Shariff, S. Balasundra, S. Yahaya An agricultural investment map based on geographic information system and multi-criteria method *Journal of Applied Sciences, 10 (2010), pp. 1596-1602*

Eshett, E.T (2003). The basaltic Soils of South Eastern Nigeria: Properties, Classification and constrains to productivity. Journal of Soil Science, 38: 565-571.

Esu, I.E (2005). Characterization, Classification and Management problems of themajor soilorder in Nigeria, 25th inaugural lecture, University of Calabar. FAO/UNESCO, (2014). Soil Map of the World 1.500,000-Legend Sheet and Memoirs.The United Nations Educational, Scientific and Cultural Organization.Pp: Embrechts, J.V.M., PoeloenganZulkarnain& SYS, C.C. (1989). Comparison of physical land evaluation using a parametric method with land characteristics and with land qualities. Application on oil palm plantationsin North-Sumatra (Indonesia). In: J. Bouma& A.K. Bregt (Eds.), Land qualities in space and time. Pudoc, Wageningen, pp. 313-316.

FAO (1997).Land quality indicators and their use in sustainable agriculture and rural development. FAO Land and Water Bulletin 5, 212p.

FAO (2007). Land Evaluation Towards a Revised Framework. Food and Agriculture Organization of the United Nations, Rome, Italy.

FAO (2006).Guidelines for Soil Descriptions 4^{th}Edition. Food and Agricultural Organization of United Nation FAO), Rome, Italy. Gaines TP and GA

FAO/ISSS (2006).Guidelines for Soil Descriptions 4^{th}Edition. Food and Agricultural Organization of United Nation FAO), Rome, Italy. Gaines TP and GA

Fetter, C.W. (1998). *Applied Hydrogeology*, Macmillan publishing co. New York. Gee, G.W. and Bauder, J.W. (1986). Particle–size analysis. In methods of soil analysis. A Klute (Ed). Part 1. 2^{nd}ed. Agron. ASA and SSSA, Madison WI.P383.

He, Y. Yao, Y. Chen, L. Ongar (2011) Land Suitability Assessment for Tree Crops Using Remote Sensing and GISComputer Distributed Control and Intelligent EnvironmentalMonitoring (CDCIEM) IEEE, Changsha, pp. 354–363

Idoga, S., Tbanga, I.J. and Malgwi, W.B. (2006). Variation in soil toposequence in Samaru area, Nigeria. Pp. 19-25. In proceeding of the 31^{st} annual conferenceof Soil Science Society of Nigeria. Ahmadu Bello University Zaria, Nigeria. November 13- 17.

IITA (1979): Selected methods for soils and plant Analysis Manual series No. 1 IITA. International Institute for Tropical Agriculture

Jamalu, G.Y and Oke, D.O (2013). Soil Profile Characteristics as affected by Land use system in the Southeast Adamawa state, Nigeria. Journal of Agricultureand veterinary Science.Vol. 6 (4): 04-11.

Maniyunda, L.M. and Malgwi, W.B. (2011).Physico-chemical Properties and Management Strategies for Soil along river Galma, Zaria, Nigeria. In: Adebayo, M.K.A.,Odofin, A.J., Osunde, A.O., Bala, A. and Oyeniyi, S.O. (Eds). Soil Resources Management Global Climate Change and Food Security. Proceeding of the 35^{th} annual comference of SSSN/Minna, Niger State, march 7^{th} – 11^{th} 2011.

Noma, S.S., Ojanuga, A.G., Ibrahim, S.A., and Iliya, M.A. (2004). Detailed Soil Survey of the Sokoto Rima Flood plain at Sokoto, Nigeria. In Salako, F.K, Adefunji, M.T., Ojanuga, A.G, Arowolo, T.A. and Ojeniyi, S.O. (Eds).Managing Soil Resources for Food Security and Sustainable EnvironmentProceeding of the 29^{th} annual conf. of SSSN/University of AgricultureAbeokuta, Nigeria, Dec.6-10, 2004.

Nottidge D.O (2011). Effect of animal manure on soil chemical properties and Productivity of pepper (capsicum annum L)in derived savannah ultisol In:W.A.hassan,U.B.kyiogwum, H.M.tukur,J.K

Odunze, A.C (2006) Soil Properties and Management Strategies for some subhumid savanna zone Alfisols in Kaduna State, Nigeria. Samaru *Journal of Agricultural Research* 22: 3-14.

Rhoades, J.D. (1982). Cation exchange capacity.*In:* A.L. Page (ed.) Methods of soil analysis. Part 2: Chemical and microbiological properties (2nd ed.) Agronomy 9:149-157.

Sanda, A.R., Ogunwale, J.O., Oluwasemire, K.O. and Raji, B.A. (2007). Effects of D rainage water recycles and irrigation scheduling on soil properties and yield of tomoto under a high water table in Northern Nigeria. In Uyovbisere, E.O, Raji, Schoeneberger, P.J, Wysocki, D.A, Benham, E.C. and Broderson, W.D. (Eds) (2002). Field book for describing and sampling soils, version 2.0 Nat. Soil Survey Centre. NRCS, USDA, Lincolns, NE.

Schoeneberger, P.J., Wysocki, D.A., Benham, E.C. and Broderson, W.D. (Eds). (2002). Field book for describing and sampling soils, version 2.0 Nat. Soil survey center. NRCS, USDA, Lincolns, NE.

Sims, T. (2000).Soil Fertility Evaluation.P .D 113-D-153. In sumner. M.E. ed(ed). Handbook of soil Science, CRC Press, Washing ton DC

Soil Survey staff (2014). Crop rotations and nitrogen fertilization to management. Pp.72-74.

Soil Survey Staff (2004).Ninth edition. United State Department of Agriculture. Natural Resources Conservation Service; 9, pp.659

Soil Survey Staff. (1999). Soil taxonomy: A basic system of soil classification for making and interpreting soil surveys, 2nd edition. Natural Resources Conservation Service. U.S. Department of Agriculture Handbook 436.

Suharta, N. and B. H. Prasetyo, (2007). Mineral composition and physiochemical properties of orest vegetated soils from acidic sedimentary rocks in Riau province. *Land and climatic Journal*. 28, 1-14.

Sys C, Van Ranst E, and Debaveye J (1993). Land evaluation. Part3: Crop requirements. Agricultural Publications 7,3. General Admistration of Development Cooperation of Belgium, Brussels, 199 p.

Udoh, B.T, Henry, H.B, and Akpan, U.S. (2011). Suitability evaluation of alluvial soils for rice (Oryza sativa) and Cocoa (Theobroma cacao) cultivation in an acid sand area of south-east Nigeria. *Journal of innovative Research in Engineering and Science 2 (3): 148-161).*

USDA, (2014).Keys to Soil Taxonomy. 12thEdn, United Department ofAgriculture,Washington, Dc, pages: 36

Walkley, A. and G.A. Black, 1934. An examination of a Degtjareff NHO for determining soil organic matter and a proposed modification of achronic acid titrate. Soil Sci, 37: 238.

Yakubu, M., Baraya, S., and Noma, S.S. (2011). Assessment of soil and water quality along river Kadarko in Sanyinna District, Sokoto State. In Hassan, W.A. Kyiogom, U.B. Tukur, H.M. Ipinjolu, J.K. Maigandi, S.A. Singh, A., Ibrahim, N.D., Dikko, A.U.,

Yakubu, M. (2006) Genesis and Classification of Soils Over different geological formations and surface in the Sokoto plains, Nigeria.PhD thesis. Soil Science and Agricultural Engineering Department Usman Danfodiyo University Sokoto (unpublished).

Zonneveld, I.S (1989). The land unit – a fundamental concept in landscape ecology, and its applications Landscape Ecology, 3: 67-86