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CATENARY SOIL VARIABILITY AND ITS MANAGENT IMPLICATION ALONG LOKO TOPOSEQUENCE, NORTHEASTERN NIGERIA

H. MUSA
Department of Soil Science Modibbo Adama University Technology, Yola, Nigeria
E-mail: hassanfuty@yahoo.com

Abstract: The study was conducted using GIS and Remote Sensing technique along with conventional Soil surveying to evaluate loko flood plain. Topographic sheet of the study area was obtained, Digital terrain model was created from the topo map, and slope map was extracted from the digital terrain model (DTM) which was classified into different categories. Each slope category was classified as soil mapping unit. Profile pits were dug on each of the delineated units, Soil samples were taken from genetic horizons. Result obtained was used to taxonomically classify the Soils. Mapping unit One soils are generally deep, the upper horizons are mostly sandy to silty loam underlined by silty to sandy clay, yellowish brown in colour (dominantly hue 10 YR) The structures of the top soil is medium sub angular blocky with a weak to moderate grade. Consistence ranges from non-sticky, non-plastic at the upper horizon and slightly sticky to sticky at the subsurface horizons and was classified as fluventicendoquepts, Mapping unit Two soils are generally deep, texture of the pedons are characterized by sandy clay loam at the surface horizons and sandy clay at the subsurface. They are yellowish brown in colour (dominant hue 10YR) and are poorly drained as indicated by the presence of mottles within the pedon, and classified as typicendoaqualfs. Mapping unit There are generally shallow, pedons not reaching 100cm. Textures are sandy loam and sandy clay at the surface and sub-surface respectively. The colours are dominantly yellowish brown (dominant hue 10YRa). The structures are weak, friable sub angular blocky at the surface and strong medium sub angular blocky subsurface, the consistent are non-sticky, non-plastic at the surface and a weak, medium sub angular blocky, very sticky and very plastic sub surface. The Soils are classified as aquicustorthents. This study revealed that strong relationships exist between topographic position and soil properties. Soil depth are shallow at the crest and gets deeper down the slope while structure improved downslope .Soil texture becomes less finer with bulk density increases as the slope position increases upward. Consequently these changes in soil properties across the slope positions have influence on land use and management such that each slope position has different crop types and management strategy.

INTRODUCTION

The challenge of agriculture in the 21st century requires an integrated and systemicapproach. This approach must address sustainable use and management of naturalresources through development and adoption of farming technology and management practices that will ensure

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food security and agricultural livelihoods. Over the next 50 years, the world population is projected to increase by some3 billion, primarily in the developing countries. Yet, even today, some 800 millionpeople go hungry daily, and more than a billion live on less than a dollar a day (FAO 1996).

Without social, economic, and scientific progress, more than a third of the world's expected 9 billion population could be living in poverty in the second half of this century. One of the major draw backs in agricultural production in developing countries especially sub-Sahara Africa is the lack of specific information of the soil that best suitable for particular crops or managements, compared with developed countries where some thousands of soil series and types have been described and named in a complete card index (Jack, 1959).An understanding of the basic properties is essential for developing soil management practices that will maintain the productive potential of a soil. The journey towards self-reliance and self-sufficient in agriculture production begins with an adequate understanding of the soils properties. The need for improved crop productivity is more now than ever because sizeable areas of productive lands in the country are becoming infertile and consequently there appear to be a threat to the national food security. In agriculture, land is among the most important renewable, dynamic resources. Therefore comprehensive, reliable and timely information on land resource is very much necessary for Nigeria whose main stay of the economy is agriculture. In addition, with increasing population pressure throughout the nation and the concomitant need for increased agricultural production, land resources management is not only imperative but necessary. In order to accomplish this, it is first necessary to obtain variable data on not only the types, but also the quality and quantity and location of these resources.

MATERIAL AND METHOD

Study area

The study area is located at about 5km to Song town along Yola – Mubi road; The area is located between Latitude 09^0.46.0"N - 09^0.52.0"N and Longitude 12^0.31.0"E- 12^0.40.0"E and lies at an elevation of about 257m above sea level. The area is located around the foot toe of the famous three sisters rock of song with few undulating areas at a slope of about 2-6 %. Loko area is within the northern guinea savannah zone which is characterized by tall grasses with few trees and many shrubs (Figure1). Temperature in this region is high throughout the year because of the high radiation influx which is relatively evenly distributed throughout the year. Seasonal change in temperature occurs in this region, there is a gradual increase in temperature from February to May, the maximum usually occur in April/May and drops at onset of rains due to cloudiness. Maximum temperature in the state can reach 40^0C with the mean monthly range of 26.70^0C in the north eastern part (Adebayo, 1997).

Rainfall is the most variable element of the tropical climate; most of its characteristics such as amount, frequency and intensity vary widely in time and space. The movement of the inter-tropical discontinuity (ITD) and it associated zones of rainfall during the course of the year is the major factor controlling rain fall in the state (Adebayo, 1997). There is hardly any rainfall received between November and February in the area. Rainfall amounts ranges between 700 – 1000mm annually which falls between May – October. The peak periods of the rains are between July – September.

The geology of the area as reported by Adekeye and Ntekim (2004) and Bassey (2005) reveals that the area is characterized by a basement complex area of the Hawal basement complex, the major groups of rocks are gneiss, magmatites and granite, the dominant rocks are highly intruded by a series of granite, pegmatic and some basic rocks.The area is moderately drained which could be attributed to the network of streams whose courses are controlled largely by the geological structure. The major drainage channel of the area is the river flowing through the area from Dumne Mountains which flows in the west east direction. The river when full in years of heavy rainfall overflow its banks at Loko town because of its relatively low slope position compared to the Dumne high hills through which it flows. The over flow from the river is the Source of the Loko flood disaster which causes damage to farm lands, residential house and even animals and human life's sometimes lost.

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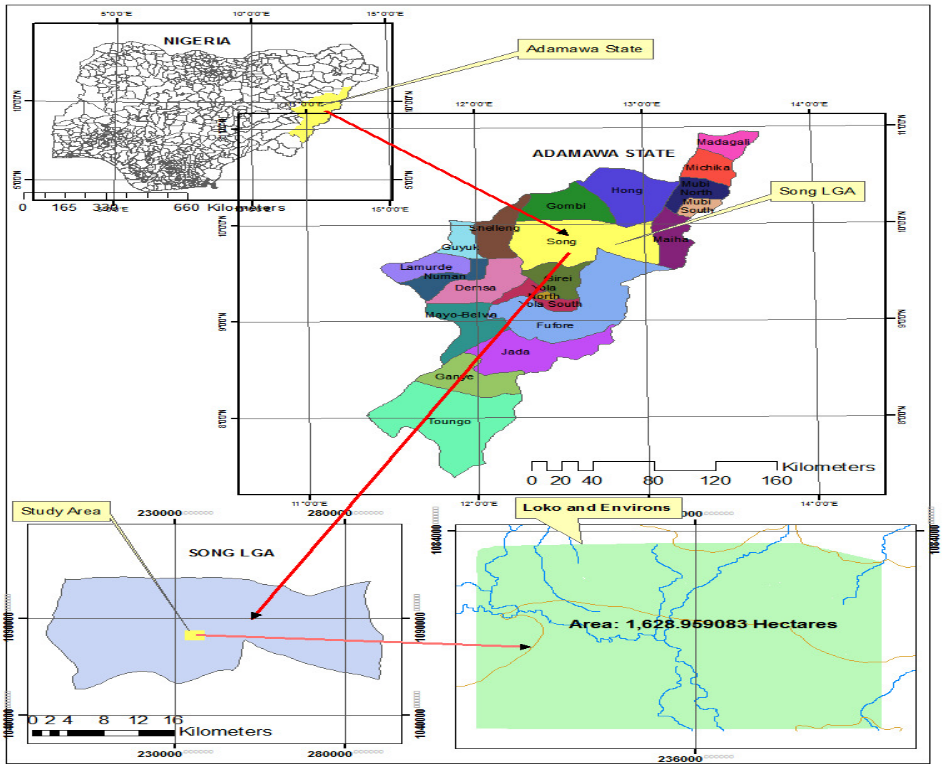

Fig.1: Map of Nigeria showing location of the study area

Field Study

GPS was used to collect XYZ coordinates on the ground this was used to obtain topographic sheet of the study area .Digital terrain model(DTM) of the study area was created from the topographic map, slope map was extracted from the DTM which was classified into different categories. Each slope category became a soil mapping unit.

The Arc GIS tools, spatial analyst and x-tool was activated to carry out the terrain analysis. The boundary of the study area was generated with x-tool through the convert poly line from points command while the total area was computed with the inquiry (area tool)information obtained on the map was used to delineate mapping units/sampling points on the ground. A systematic special purpose grid system detailed Soil survey was adopted for ground- truthing of the computer delineated mapping units to establish the actual soil boundaries on the field, rigid auguring at 50m intervals was made and physical and morphological properties were recorded for use in demarcating the mapping units' boundaries.

Five Profile pits were dug on each of the delineated units and described according to Soil survey staff, (1993). Soil samples were taken from genetic horizons and taken to the laboratory for analysis following the method of the revised methods of soil analysis by Jaiswal (2004).

Laboratory Analysis

Routine analysis of the soil samples collected was carried out in the laboratory using standard procedures. pH and electrical conductivity (EC) of the soil was analysed using the Genway Model pH meter at 1:2.5 soil to water ratio and organic carbon was determined using the Walkley Black method. Nitrogen was analysed using Kjeldhal digestion procedure while available phosphorus was determined using Bray-1/ Olsen as soil pH dictate. The ammonium acetate (NH_4OAC) extraction procedure was used in extraction of the exchangeable bases and contents determined using flame photometer and titration method for Na and K and calcium and magnesium respectively. Titration method was used in the determination of exchangeable acidity. Total exchangeable bases (TEB) were obtained by summing the exchangeable bases (Ca^{2+}, Mg^{2+}, Na^{+}, and K^{+}). Summation method was used in calculation of ECEC (IITA, 1984) and base was calculated as a percentage of TEB and ECEC (IITA, 1984).

Means, ranges and percentages and Coefficient of Variability (CV) were used for the analysis of data obtained.

RESULT AND DISCUSSION

Based on the results obtained from the morphological, physical and chemical analysis, the Soils of the study area were classified according to the USDA Soil taxonomy. Result obtained was used to classify the Soils of the study area. Mapping unit 1 soils were generally deep, the upper horizons are mostly sandy to silty loam underlined by silty to sandy clay, generally yellowish brown in colour (dominantly hue 7.5 YR) while the upper horizons were darker in colour. The structures of the top soil is medium sub angular blocky with a weak to moderate grade. Consistence ranges from non-sticky, non-plastic at the upper horizon and slightly sticky to sticky at the subsurface horizons. The mapping unit have a Hue redder than 7.5YR in more than 50 percent of the matric in the horizon between the Ap and a dept of 75cm below the mineral soil, they also have chroma of more than 2. They have organic carbon content of more than 0.2% at depth over 100 cm below the mineral soil surface. The soils are therefore classified as fluventicendoquepts at the sub group level.

Mapping unit 2 soils were generally deep, texture of the pedons are characterized by sandy clay loam at the surface horizons and sandy clay texture at the subsurface horizons. They are yellowish brown in colour (dominant hue 10YR) and are poorly drained as indicated by the presence of mottles within the pedons. Mapping unit two Soils horizon have aquic conditions, enough active ferrous iron to give a positive reaction to alpha-dippyridyl at a time when the soil is not being irrigated.

The units are further classified as endoaqualfs at the great group level as they do not fall in to other categorization of aqualfs. They are typicendoaqualfs in the sub group level. Mapping unit three were generally shallow, pedons not reaching 100cm as a result of the presence of bedrock at the sub surface. Textures of the pedons are characterized by loamy sand and gravelly clay at the surface and sub-surface respectively. The colors were dominantly reddish brown (dominant hue 7.5YR). The structure of the pedons are weak, friable sub angular blocky at the surface and strong medium sub-angular sub-surface. The consistencies are weak, non-sticky, non-plastic at the surface and vary sticky, vary plastic sub-surface. The Soils are young and developing with little mineral horizon differentiation and are therefore classed as orthents in the great group level, the unit are classified as Ustorthents as they are known to have an ustic soil moisture regime, and as aquicustorthents in the suborder category as they have, in some horizon within 100 cm of the mineral soil surface, redox depletions with chroma of 2 and also aquic conditions for some time in normal years.

Physical and morphological properties of Loko floodplain:

Mean and standard deviation of some physical and morphological properties of the soils are presented in Table 1. The soil texture varied widely from loamy sand in MU1 and MU2 to sandy clay loam in MU3. The soils of MU3, and MU2 a have low water holding capacity and were partly saturated at the surface pedon. MU1 was either partly or permanent saturated and as such belong to aquic soil moisture regime. These properties are attributed to either a periodically high water table and/or slow infiltration of surface water resulting from relatively moderately clay content, particularly in MU1. The silt and clay contents show an increase with increase in depth in all the mapping units of the floodplains while, sand content decreased, a phenomenon which Essoka and Esu described as clay migration by lessivage to produce the process of illuviation. (Gregory S and Trenchard O.I (2009). The soilscolours varied from 10-5 YR. The properties showed either as grey colour throughout, grey mottles or soft reddish concentrations and staining in the soil profiles. The surface soil colour varied from dark brown to yellowish brown.

Table 1: Some Physical Properties of LokoFloodplains

Mapping Unit	Sand	Silt	Clay	Texture	Colour (moist)
Mapping Unit One	21.60±54.04	56.40±24.49	22.00±41.47	LS	10-7.5 YR
Mapping Unit two	45.15±29.63	25.29±26.67	29.56±16.67	SL	10 YR
Mapping Unit Three	08.20±84.38	70.80±21.91	21.00±66.93	SCL	10-5 YR

LS = Loamy sand, SL = Sandy Loam, SCL Sandy Clay Loam,

Chemical properties of Loko floodplain

The pH values in soils varied from slightly acidic to slightly alkaline in the floodplains (Table 2). In all the mapping unit, the pH values in water suspension were higher than corresponding values in IMKCI solution, indicating that all soils at their natural pHs are negatively charged. Electrical conductivity of the saturation extract was low, being <id Sm-1 in all the soils, indicating non saline nature of the soils. Therefore, the soils will not pose any salinity problems to crops that would be grown. Salinity problems are usually encountered for sensitive crops when EC_{25} is above 2 d Sm-1 Exchange acidity and exchangeable A1 were variable and moderate in the soils with mean percent A1 saturation being generally <30% (18.7-29.3%).Exchange acidity and exchangeable A1 had the highest intercorrelations with other soil properties in the soils (Table 2), indicating the strong relation between the physical surface area characteristics and chemical composition in these acid soils.

Table 2: Mean and Standard Deviation for Soil Chemical Properties of LokoFloodplains

Mapping Unit	pH H_2O	pH KCl	EC25o (d.sm^{-1})	Org. C	Tot. N gkg^{-1}	C/N	Av.P (mg kg^{-1})
Mapping unit one	5.2±2	4.5±1	0.092±1.02	13.2±2	0.06±0.1	24±1	11.30±6
Mappimg unit two	5.2±1	4.6±0.3	0.110±0.03	16.30±2	0.7±0.1	24±1	12.03±4
Mapping unit three	4.9±0.1	4.4±0.3	0.041±0.03	9.8±4	0.4±0.2	23±2	7.28±3

Table 2: Cont'd

Ca	Mg	K	Na	EA	EAI	CEC	BS (%)
1.15±0.2	0.50±0.06	0.08±0.02	0.05±0.01	1.25±0.044	0.58±0.37	1.78±0.27	59.7±6.6
1.72±0.3	0.97±0.22	0.09±0.07	0.06±0.01	2.22±0.94	1.27±0.47	2.83±0.52	56.5±9.9
1.76±0.16	0.74±0.11	0.08±0.02	0.04±0.01	3.89±1.48	1.91±1.18	2.62±0.26	42.3±12.6

EC = Electrical conductivity, Org. C = Organic C, Tot. N = total N, C/N = Carbon to N ratio, Av.P = Available, EA = Exchange Acidity; Eal = Exchangeable A1, CEC = Cation Exchange Capacity, BS = Percent Base Saturation

The soils have a substantial amount of organic C contents (Table 2). These values translate into organic matter contents of 22.8 gkg-1 for MU1, 28.1g kg-1 for MU1, 16.9 and 21.6gkg-1 for MU3 respectively. The observed values were due to high productivity and high decomposition and mineralization rates in the environment, resulting in the low organic matter in soils. The result shows that organic matter is the main source of total N and BS and contributes slightly to K and Na concentrations in the soils. Total N levels were low with values in MU1 and MU2 being lower than in MU3 and available P showed mostly significant negative correlations with basic cations (Ca, Mg, K) and CEC (Table 2). On this account the nutrient status of the soil may be defined in terms of saturation of the exchange complex by Ca, Mg and to a lesser extent by K. CEC values in the soils were low and varied from 1.72+0.38 in upper slope to 2.83+0.52 cmol kg-1 inlower slope. Although, CEC was low, percent base saturation was high except in the study area where BS was below 50%, the separating index between fertile and less fertile soils. Exchangeable Ca means in the floodplains were <4.0 cmol kg-1 regarded as the lower limit for fertile soils. In contract, exchangeable Mg levels varied from moderate to high in the soils with mean values >0.5 cmol kg-1, the indicative minimum for Mg availability.

Exchangeable K was the least nutrient in the flood plain and is positively, though weakly, correlated with organic C.

Management implications

Site-specific soil management is the process of managing soils based on localized conditions within field boundaries which affect crop yield. To be effective, management schemes must address both soil variability and soil properties limiting yield.

The study area is characterized by three topographic positions which requires crop selection and different management practices across the catena. Soils of the crest are characterized by shallow depths, coarse textured, high slope gradient and low porosity. These characteristics results to low available water holding capacity because the ability of the soil to retain water depends largely on soil depth, the coarse texture also means low cation exchange capacity which consequently implies low ability of the soil to retain added nutrients for plant use. The shallow depth of the upper slope Soils also means that aeration, root penetration and development will be restricted. For good utilization of these soils, management techniques such as leaving the soil surface rough by adopting end of season Ploughing for improved infiltration rate , reduction of surface runoff and avoidance of surface crusting through sun baking. Johns, M.J and Wild (1975). This practice also have the advantage of incorporating organic residues into the soil to improve soil structure and reduce soil bulk density. (S. Idogaetal 2006). The choice of suitable agronomic practices on this slope position are also required, these include strip cropping and use of cover crops which are measures that can check surface run off and improve infiltration capacity of the soils.Other management options for soils on this slope position include choice of appropriate crops that can be suitable to such soils, these include cowpea and groundnut.Soils of the middle slope position are more developed than soils of the upper slope position and as such are characterized by deep,well drained soils which can support a wide range of crops and requires less management practices as compared with the soils on the upper slope position.However, incorporation of organic matter is recommended for soils on this slope position. Proper maintenance of soil organic matter is an important part of nutrient management, Organic matter enhances both chemical and biological soil properties, as well as supplying sources as macro- and micronutrients. The most stable form of organic matter—humus—plays an all-important role in improving soil structure, nutrient retention, and water storage. Additionally, it has been shown that additions of animal and green manures, as well as compost, enriched microbial activities in the soil. Soils on the lower slope position are very well developed and are characterized very deep soils, they have relatively low bulk density and high porosity with fine surface textures underlined by a coarse textured sub surface soils. These soils are sometimes flooded and are characterized by imperfectly to poorly drainage conditions. If properly drained this soil can support a wide variety of crops .The best way to utilize the soil on this slope position is practice dry season farming or should be cultivated to early maturing rice, maize or sugarcane.

Conclusion

This study revealed that strong relationships exist between topographic position and soil properties. Soil depth are shallow at the crest and gets deeper down the slope while structure improved downslope .Soil texture becomes less finer with bulk density increases as the slope position increases upward . Consequently these changes in soil properties across the slope positions have influence on land use and management such that each slope position has different crop types and management strategy.

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