# CHARACTERIZATION, CLASSIFICATION, AND EVALUATION OF SOILS OF FOUR GEOMORPHIC SURFACES IN OGUTA IMO STATE SOUTHEASTERN NIGERIA

**BY**


**NWACHUKWU, OGECHI MERCY**

**B.AGRIC**

**2012476O348**


**A THESIS SUBMITTED TO THE POSTGRADUATE SCHOOL**

**FEDERAL UNIVERSITY OF TECHNOLOGY, OWERRI**

**IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF THE DEGREE OF MASTERS OF SCIENCE (MSc.) IN SOIL SCIENCE AND TECHNOLOGY FEDERAL UNIVERSITY OF TECHNOLOGY, OWERRI.**

**JUNE 2016.**

## CERTIFICATION

This is to certify that this work "CHARACTERIZATION, CLASSIFICATION, AND EVALUATION OF SOILS OF FOUR GEOMORPHIC SURFACES IN OGUTA IMO STATE SOUTHEASTERN NIGERIA" was carried out by **Nwachukwu, Ogechi Mercy** with Registration Number **20124760348** in partial fulfillment for the award of the degree of Masters of Science (M.Sc.) in the Department of Soil Science and Technology, Federal University of Technology, Owerri.

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**Dr. Emmanuel U. Onweremadu**
Supervisor

13/07/2016
........................................
**Date**

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**Dr. Emmanuel U. Onweremadu**
(Head of Department)

13/07/2016
........................................
**Date**

........................................
**Prof. B.O. Esonu**
Dean of SAAT

14/07/16
........................................
**Date**

........................................
**Prof. (Mrs.) Nnenna N. Oti**
Dean of Post Graduate School

........................................
**Date**

........................................
**External Examiner**

........................................
**Date**

## DEDICATION

I dedicate this research work to Jehovah, to my lovely parents Mr. and Mrs. Joseph Nwachukwu for their parental care throughout the duration of this programme.

## ACKNOWLEDGEMENT

My greatest thanks go first and foremost to Jehovahthe Almighty God for giving me the knowledge, wisdom, and understanding to silver-tongue this work. I acknowledge the encouragement, contributions, corrections, and tutoring of my supervisory committee membersfor their invaluable inputs which will remain evergreen in my mind.Special thanks to my principal supervisor, Director, Center for Agricultural Research, Dr. Emmanuel Onweremadu, for spending a lot of time to read this thesis and providing useful contributions to it; the H.O.D. Department of Soil Science Technology,Prof. Mrs. Nnenna Oti, Prof. G.E. Osuji, Prof. E.T. Eshett, Dr. B.U. Uzoho, Dr. C.M.Ahukaemere, Dr. B.N. Ndukwu,Dr. I.I. Ekpe, Dr. E.E. Ihem, Dr. U.N. Nkwopara, Dr.S.U. Onwudike, Dr. L.E Agim, and all the lecturers and staff in the Department of Soil Science for their mentoringattitude.

I appreciate the concern shown by Chief, Nze, Dr. Francis Okorocha, Mr. Gilbert Ekeh, and Mr. Andrew Wenibo. Last but not the least important, I owe more than thanks to my family members, especially my parents and my siblings for their care and support throughout the course of compiling this thesis.

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# ABSTRACT

This research was carried out to characterize, classify, and evaluate soils of four geomorphic units in Oguta Imo State Southeastern Nigeria. Four Pedons, each was located in each geomorphic unit. ] soil sampling was carried out in the study site, sixteen surface soil samples (0-20 cm) were collected, four from each of the geomorphic units using an auger giving a total of thirty three soil samples which was chosen to represent the main morphological variations and to present mapping units throughout the soils of Oguta Imo state Southeastern Nigeria. Results of the laboratory analysis showed that the soils were predominantly sandy loam and loamy sand. Texture was coarser at the terrace than the levees and backswamp. The soils in the levee crest, were classified into subgroup Typic Eutrudepts, levee slope and terrace Typic Hapludults while soils of backswamp were classified as Typic Endoaquepts. The soils were classified into land capability class II, III, IV and V with limitations due to nutrient holding capacity (n), wetness, (w) and angle of slope (a). The results of the land suitability classification for wetland rice production showed low suitability (S3) for all the soils. Land suitability classification for cassava production showed moderate or medium suitability (S2) for the soils of levee crest, levee slope and terrace, while the soil of backswamp has low suitability (S3). However, soils of levee crest – backswamp (EO1EO4), levee crest surface soils - terrace surface (EO1S-EO3S) showed moderate or medium suitability (S2) for maize production while backswamp surface soils (EO4S) showed low suitability for maize production. Land suitability classification for Sugarcane production showed moderate/medium suitability (S2) for all the soils in the studied geomorphic units. Data generated from various analyses were subjected to analysis of variance (ANOVA). Correlation analysis was used to estimate degree of relationship among soil properties. The results of fertility capability classification (FCC) showed uniform loamy top and subsoil. The major limitations of the soils for crop production are soil texture and structure, which directly affect waterholding capacity, permeability of the soil among other soil physical properties.

**Keywords:** Geomorphic, Evaluation, Suitability, Inceptisol, Entisol

# CHAPTER ONE

## 1.1 INTRODUCTION

Proper management of the world soil resources can ameliorate the global problem of hunger and malnutrition (Brady and Weil, 2010).

The population of the world and that of the sub-Saharan Africa in particular since the late 1960's is increasing at an alarming rate with no corresponding increase in food production to meet the teaming population (Wahua, 2002).

Owing to this increase in population, there is an increasing demand on land for non-agricultural purposes such as construction activities, increased urbanization, and industrialization in other to meet the ever increasing demand on food, there is need to effectively harness the underutilized Oguta coastal plain soils and alluvial soils for effective agricultural activities. Agricultural productivity is declining because of inadequate scientific knowledge among local farmers there is the need to surpass the stage of farming by trial and error via knowing the potentials and limitations of a land in other to get maximum productivity and efficiency from land (Wenibo 2012).

The geomorphic surface concept allows interrelationship among various branches of soil sciences, such as geology, geomorphology and pedology. This association enhances the understanding of spatial soil distribution through landscape, pointing out the soil attributes behavior, which are mainly related to stratigraphy and relief forms. The digital mapping of soil classes generally starts with soil profile description organizing the soil classes at a taxonomic level in a particular classification system

The indispensability of soil survey information rises as Krall and Lee (2004) reported a widened spectrum of usage of detailed soil information bringing in other soil users, and this becomes imperativein Oguta where thereare many underutilized soils due to over dependency on upland.Soils derived from coastal and alluviums occupy a distinctive and important place in tropical agriculture.

Ogutais on alluvial and coastal plain with a lot of promising agricultural potentials but have been grossly underutilized owing to over dependency on upland soils for crop production. Farmers are more interested in land evaluation system that will give them relevant information on the relative capability of a piece of land for alternative uses, such as the fertility levels, toxicity levels, capability level for forestry, the crops that can bring most profitable results from the land, and the limitations of the land to various uses and how to overcome them (FAO 1991)

Although several studies have been carried out on the soils of Oguta coastal plain soils and alluvial (Nwosu *et al* 2011) soils some scholars have also worked on the geomorphic surfaces of soil(Doer *et al,* 2000 Onweremadu *et al* 2007; Parizanganeh *et al.*,2007). However, data on the specific properties of soils in Oguta were not covered by the research works and as such farmers have found it difficult to obtain the needed scientific information to manage the soils for better agricultural benefits. Among the researches on soils of Oguta none have covered the soils of Egwe, thus the need for the resent investigation. This research covered the characterization, classification land evaluation methods based on USDAsoil taxonomy/FAO and World Reference Base.

The findings of this research would add to the wealth of information on the soils of Oguta and would provide adequate information to land users on the effective management of the soils for increased productivity.

## 1.2The Major Objective of the Study was to:

Characterize, classify and evaluate the potentials of the soils of four geomorphic surfaces at Oguta in Imo state, Southeastern Nigeria for crop production.

## 1.3Specific Objectives Include to:

- Estimate variability among soil groups
- Determine relationship among soil properties
- Evaluate the potentials of the soils for the production of some crops.

# CHAPTER TWO

## Literature Review

A good understanding of the pedological properties of soils is considered as the fundamental base for a successful agricultural development of soils. A survey of the soils of Southeastern Nigeria will enable farmers and other land users to have a comprehensive knowledge of the soils for effective manipulation of agricultural gains. Characterization and classification of soils of any given location help in generating soil and soil-related data which are useful in sustained use of soil resource. Non-use of soil survey data has resulted in soil and soil-related environmental problems like nutrient depletion (Onweremadu, 2006) compaction, flooding, and poor yield (Zinck, 1990).

### 2.1Geology and Geomorphology of Coastal Plain Sandsand Alluvial Soils

The soils of Oguta Imo State Southeastern Nigeria are derived from geologic materials of tertiarycoastal plain sands and alluvial materials which are recent deposits of alluvium that have been affected only by slightly soil forming process such as the incorporation of humus and the development of mottled color owing to poor drainage (Young 1976).Coastal plain deposits otherwise referred to as Benin Formation is made up of continental sands and sandstones (>90%) with a few shale intercalations (Nton and Esua, 2010). The physicochemical properties of interest include particle size distribution, soil pH, organic carbon, available P, exchangeable bases, exchangeable acidity among others. These properties of soils have been used as soil quality indicators to assess the Soil Degradation Rates (SDR) and Vulnerability potential (Vp) with the aim of understanding the productivity of the soils under agricultural management systems (Lal, 1994; Akpan-Idiok *et al.*, 2012).

Worldwide, coastal plain soils are variable and agriculturally with inherent limitations. The coastal plain soils of Southeastern United States of America are characterized by low soil fertility, sandy texture, acidic pH values, low contents of basic cations, organic carbon and activity clays; the soils are strongly weathered and are classified as Ultisols under USDA Soil Taxonomy and are cropped to corn and cotton (Shiyam *et al.*, 2007; Novak *et al.*, 2009). The Swan coastal plain soils in West Australia are porous, thus favoring leaching of applied nutrients and pesticides from the soil surface (Salama *et al.*, 2001). The coastal plain soils in Somalia consist of alluvial and marine deposits and are poorly developed and shallow probably due to less amount of rainfall (50-200 mm) in the region (Sommerlatte and Umar, 2000).

In Nigeria, they are among the soils that occupy Oguta Imo State Southeastern Nigeria. They are strongly weathered and are characterized by coarse to fine sand texture in the surface to subsurface soils, low contents of organic carbon, total nitrogen, exchangeable bases, activity clays (kaolinite) and low/high content of available phosphorus. The soils are highly leached and are therefore, slightly acidic in reaction probably due to high amounts of rainfall in the area (Udo, 1977; FPDD, 1990; Ogban *et al.*, 1998; Chikezie *et al.*, 2010).The soils support a lot of agricultural crops such as tree crop plantations (oil palm, rubber, coffee, kola nut, etc.) and food crop production such as cassava, yam, cocoyam, vegetables, maize, etc. The soils produce most of the food crops available in Oguta metropolis.

## 2.2Formation and Developmentof Alluvial Soils

Young (1976), classified pedogenic processes occurring in alluvial soils into sedimentation, homogenization and ripening. Sedimentation takes place where the speed of flowing silt-laden water is slowed down. The soil particle size deposited depends on the velocity of the flow. Homogenization is the elimination of depositional layering mainly textural. The agents involved in the early stages of homogenization were biological (plants roots, worms, termites, micro-organisms and in mangrove soils crabs).Young (1976).However over long period, clay translocation comes to play a part. Ripening is the draining and evaporation of excess water and development of drying cracks. This leads to consolidation andsubsidence of the clay. Proper pedogenic processes take place concurrently with intermittent sedimentation and have a greatereffect if sedimentation ceases. The degree of leaching of salts, carbonates, and bases depended on the rain fall and depth of water table (Young, 1976).

## 2.3 Propertiesof Coastal Plain Soils

The Atlantic Coastal Plain soils of pinelands, swamps and sand beaches boast rich biodiversity and subtle scenery. Most of the arable soils in Northeast are typical tropical sandy soils. Their main primary and secondary minerals are quartz and kaolinite, respectively, because parent materials have been strongly weathered. As a result of the destruction of natural vegetation to make room for cultivation, the soil organic matter is low resulting in low cation exchange capacity (CEC) and low pH. Njar *et al*(2012) Amelioration of these soils requires liming, fertilization and application of organic matter and 2:1 type clay minerals. Each of these ameliorating techniques encounters respective problems. Rather many farmers are using animal dung as an organic fertilizer for cash crops and/or rice seedlings.

This practice has some limitations. Green manure has been considered to be useful, though its extension has not been successful due to lack of proper techniques of cultivation and utilization of suitable plants. A part of the arable soils in the region are salt-affected, salinization being intensified by deforestation. Reforestation is not always effective in desalinizing the salt-affected soils, because the degree of salinization varies markedly according to the position in the relief and both short- and long-term strategies are needed.

### 2.3.1 Properties of Alluvium

Olayeye(1998)reported that the land on which alluvial soils occurred asflat lands which made them suitable for the cultivation of paddy rice and irrigation activities. Sanchez *et al*. (1985) stated that alluvial soils have high water table which gives them the characteristics gleying properties thus making them to possess aquic moisture regimes. Egbuchua *et al*., (2012) stated that characteristics of alluvial soils of the Niger Delta including Oguta varied from fine to coarse textured. The texture of alluvial soils varied from coarse sand to heavy clay. A basic distinction on flood plain is between coarse sandy sediments of levees and braided channels, in sands, silt of the main part of the plain and clays of the back swamp and other depressions (Young, 1976).

Textures of alluvial soils might be influenced by the kind of rock outcrop in the upland and might show a relation to the adjacent rock outcrop. Hardpans might occur in alluvial soils (Young, 1976; Brouwer *et al.,* 1998). Some young alluvial soils might show a dominance of medium to fine texture in the top soils while those of older flood plains might have fine textured top layers Young (1976) stated that heavier- textured horizons are stuctureless with loose consistence. In terms of soil color, Young (1976), stated that heavier soil profiles of a recent alluvium under a 500 to 1000mm rainfall, with the water table rising seasonally upto 1 to 2m depth may likely have yellowish brown to dark grayish brown coloration. This is so because iron (iii) oxide had undergone some hydration.

Drainage mottles occur with depth (Brouwer *et al.,* 1998). Brady (1999), stated that alluvial soils with a high degree of pore spaces to solid have tendency of having lower bulk densities than those with more compact and less pore spaces. He also opined that fine textured soils such as silt loams, clay and loams usually have lower bulk densities than sandy soils. He added that bulk density might increase with profile depth owing to lower content of organic matter, less aggregation and root penetration and a compaction caused by the weight of the overlying layers. Bulk density of clay loam and silt loam soils normally range from 1.0 to as high as 1.6g/cm may be found in sands and sandy loam. Very compact sub-soils may have bulk density of 2.0 mg/m or more (Brady, 1999).

Sanchez and Buol (1985), and Olaleye (1998)reported that alluvial soils are often less acidic than non-alluvial soils of corresponding climates with PH which varies from weak alkaline at the same surface. In terms of organic matter level, Brouwer *et al.*, (1998) shows that organic matter levels of alluvial soils are slightly higher than that of non-alluvial soils of comparable texture and climate. The high organic matter of alluvial soils could be attributed partially to the slow rate of decomposition during flooded periods and seasonal decomposition of the organic material from plant debris during flooding of the plain. Organic matter decomposition proceeds at a slower rate in flooded soils than in anaerobic soils because anaerobic bacteria involved are less efficient than the more diversified aerobic micro-flora (Sanchez and Buol, 1985).

Young (1976) stated that organic matter levels in alluvial soils vary from 2.0% to as low as 0.5% depending on the cultivation history and the top soil texture. Most alluvial soils of the tropics have a Cation exchange capacity range of 7.2-17.2meq/100gindicating the presence of illiteand chloride as common minerals (Young, 1976, Esu, 1999). Jones (1982); Sanchez *et al*., (1985), confirm that most alluvial soils have low nitrogen level due to the fact that after flooding, nitrates quickly disappears and $NH_4$+ content increases because the absence of oxygen inhibits the activity of nitrosomonas and micro-organisms that oxidizes $NH_4$+ to $N0_3^-$.Alternate flooding and drying cycleresults in tremendous nitrogen losses, which accounts for the low nitrogen content in many alluvial soils. Jones (1982) stated that flooding of alluvial soils altered the process of phosphorus fixation. Flooded soils have more available native and added phosphorus than well- drained soils. The high phosphorus status of alluvial soils is due to the reaction of iron phosphate, transformation of the various phosphorus compounds into soluble form and diffusion. According to Patrick and Reddy (1978), phosphorus fixation is more intense and less reversible under intermittent flooding than under continuous aerobic condition.

## 2.4 Geomorphic Surface Concept

Conceptually, geomorphic surfaces are land portions defined by geographic boundaries and located within time and space (Daniels*et al*., 1971; Ruhe, 1956). The knowledge and practice of these soil study concepts enable the performance of spatial variability studies and pedological assessments. In addition, it consists in an instrument to predict pedological features from still unknown areas (Marcus *et al*., 2009).

Therefore, applying multivariate statistics to categorize geomorphic surfaces in soils, so as to provide a basis for soil assessing the relationship among the properties univariate, multivariate analysis of variance, cluster and principal-component will be helpful in order to compare the four geomorphic surfaces. The univariate statistical analysis of soil attributes was not efficient enough to categorize the four geomorphic surfaces. The use of multivariate statistical techniques associated with geomorphic surface concepts make it possible to observe the soil attributes variation, thus consisting of an attempt to reduce error and to understand the sequences of pedogenic processes, and clarifying the participation and important order of soil variables (Yemefack *et al.,* 2005). The use of this techniques will categorize clusters in such a way that error rate can be classified as minimal, thus providing important information to give accurate interpretation of land use planning (Vaselli*et al.,* 1997), landscape understanding, soil attributes (Fu *et al.,* 2004; Sena *et al.,* 2002; Souza *et al.,* 2006), behavior as well as its spatial distribution, studies on soil genesis and classification (Gomes *et al.,* 1984). Siqueira *et al*. (2010), proposed the use of the soil landscape model and multivariate analysis to identify potentially productive areas in landscape for citrus orchard.

Soil classes at any taxonomic level have taxonomic relationships between each other, and in some instances the errors in prediction of certain classes are more serious than the others (Minasny, Mcbratney; 2007).In this sense, some authors (Campos *et al*., 2007; Cunha *et al.,* 2005; Sanchez *et al.,* 2005; Teramoto *et al.,* 2001) have been using geomorphic surfaces to assist in more accurate transition lines identification between the involved regions, and help in understanding of greater or lesser variability space areas.

Hence those studies on soil variability and its geomorphological attributes are aid tools in pedology studies, since they do not consider the pre-established taxonomic limits, but rather follow soil limits as natural bodies. Thus, they improve interpretations in assessments for land suitability studies, capacity use, managing zone establishment and etc. (Cunha *et al.,* 2005).

By using the physical and chemical soil properties, the multivariate statistical techniques enhances the differentiation of the four groups of soil natural bodies which were equivalent to the same four mapped geomorphic surfaces (GS). The outcome willdemonstrate the feasibility of the numerical classification use on geomorphic surfaces to assist the soil mapping.Soil classes at any taxonomic level have taxonomic relationships between each other, and in some instances the errors in prediction of certain classes are more serious than the others (Minasny andMcbratney; 2007).

## 2.5 Fertility Status of Coastal Plain Soils and Alluvial Soils

Soils are generally low in native fertility requiring lime and fertilizers for agronomic crops, and subject to erosion. The soils have developed in sandy, loamy, and clayey coastal plain sediments and in the western part some ridge tops have a thin mantle of loess Geeves *et al* (2012). In many areas, erosional material from outside the area, such as the loess from the west and clays from the Blacklands, has been added to that derived locally to give a wide range of alluvial materials in the floodplains that are fairly high in exchangeable bases (Ca, Mg, K, and Na).Mordi (1986), reported that calcium and magnesium were the dominant exchangeable bases on the exchange complex and the CEC of alluvial soils varied from very low to very high with a range of 1.9 to 4.7 meq/100g soils.Ping*et al.*, (2013), using the summation method noted that the CEC was high in alluvial soils, and this attributed to the origin and youth of the parent materials as well as the presence of easily weatherable minerals rich in nutrient cations. Loganathan *et al*, (1995)reported that the alluvial deposits formed from recent materials carried southward by Niger river from the drier climatic regions north of the Meander Belt zone were rich in vermiculite, interstratified or mixed silicate minerals, mica, feldspar, Kaolinite and quartz. In the brief descriptions of each soil, solum refers to the upper and most weathered part of the soil profile; the A, E, and B horizons. A soil horizon is indicated by the use of A, E, B, etc. standing alone. The coastal plain soils and alluvial soils support leaching of nutrients.

Generally, Inner Coastal Plain soils and alluvial soil are fertile (they can support hearty natural growth of a wide variety of plants). The upper layers of the inner coastal plain soils are brownish and remain moist between rains,Outer Coastal Plain soils are very sandy, infertile, and chemically acidic.Outer coastal Plain soils capture water well, but it quickly percolates into the lower layers. Outer coastal plainsoils have a light color. Blueberries and cranberries are well suited to growing in "infertile "soil of the outer coastal plain soils.The soils have low CEC and this is attributed to the origin and youth of the parent materials as well as the presence of easily weatherable minerals low in nutrient cations, low in organic matter content.

## 2.6 Agricultural Potentials of Coastal Plain Soils and Alluvial Soils

Udo (2001), noted that wetland soils in the Niger Delta region can be used for rainfed low rice cultivation, dry season vegetable production (tomatoes, pepper, fluted pumpkin, okra) and yam cultivation.

Isirimah (2003), noted that wetland soils can be harnessed for fish farming or aquaculture particularly where earthen ponds are involved.

It has been observed that alluvial soils have high inherent fertility, freedom from erosion, ease of irrigation water distribution and potential for double cropping.

## 2.7 Key Environmental Problems of Coastal Plain Soils and Alluvial Soils

The key environmental problems are flood; stream bank erosion, swampy terrain and pollution, particularly pollution due to oil exploration and exploitation activities.Coastal plain soils and alluvial soils are generally often subjected to flooding. The occurrence of floods is a part of a natural pattern of water circulation from the seas to the atmosphere, to the ground and back to sea again as embodied in the hydrologic circle. Typically a stream, creek or river will overflow its normal channel from time to time and invade the flood plains. The overflow occurs when the volume of water entering a stream or a river channel exceeds the hydraulic capacity of the channel (Goazalez *et al.*, 2007). In Oguta Lake, the water levels rises up to 13 meters higher in the rainy season during this high water season which lasts for two or five months each year, these rivers overflow their banks(Nwadiaro 1978). Thus in the Niger Delta, Niger river and its tributaries flood, erode, transport sediments and continuously reshape their channels. The flooding submerges land including towns and villages up to three meters in some localities (Imo Trumpeta.com). As the flood recedes, soil erosion and river bank collapsing of 2 - 5meters occurs annually.

## 2.8 Managing Coastal Plain Soils in Southeastern Nigeria

Most of the arable soils in Southeastern Nigeria are typical tropical sandy soils. Their main primary and secondary minerals are quartz and kaolinite, respectively, because parent materials have been strongly weathered. As a result of the destruction of natural vegetation to make room for cultivation, the soil organic matter is low resulting in low cation exchange capacity (CEC) and low pH. amelioration of these soils requires liming, fertilization and application of organic matter and 2:1 type clay minerals. Each of these ameliorating techniques encounters respective problems. Rather many farmers are using animal dung as an organic fertilizer for cash crops and/or rice seedlings. This practice has some limitations. Green manure has been considered to be useful, though its extension has not been successful due to lack of proper techniques of cultivation and utilization of suitable plants. A part of the arable soils in the region are salt-affected, salinization being intensified by deforestation. Reforestation is not always effective indesalinizing the salt-affected soils, because the degree of salinization varies markedly according to the position in the relief and both short- and long-term strategies are needed.

## 2.9 Land Evaluation

Land evaluation is the process of estimating the potential of land for alternative kinds of uses. These uses include arable farming, livestock production, forestry, wildlife conservation, tourism (Young, 1976; FAO, 1976; Dent, 1981). It is also known as soil survey interpretation. Therefore for soil survey to be of practical value in land use planning and management, the features of the soils, vegetation, climate etc. must be related to the requirements of different kinds of land use. The process in which the land uses are compared with qualities of land is the essence of land evaluation (Dent and Young 1981).FAO (1976) defines land evaluation as the assessment of land performance when used for specific purpose.

Ojanuga (2006) defines it as the systematic process of identifying and measuring land qualities and assessing them for the alternative kinds of use. He opined that it is based on the fundamental principles that different kinds of land use have different requirements. land use requirements refers to the set of land qualities that determine the production and management condition of a kind of land utilization types (FAO, 1976), land utilization type is a land use explained in better detail than major kind of land use and land utilization types (FAO, 1976) For example, land use for rainfed arable farming enterprise based on maize and ground nut while a major kind of land use does not necessarily specify the kind of crops.

It is basically one of the few major subdivisions of rural land use such as rainfed agriculture, irrigated agriculture, grazing, forestry and recreation (Dent and Young, 1981). Information on the different kind of land use is obtained from agronomy, forestry,and related fields whereas that of land qualities are obtained from soil survey (Young, 1976).Evaluating agricultural land management practices requires knowledge of soil spatial variability and understanding their relationshipsbecause of the fact that (a) spatial variability in soils occurs naturally from pedogenic factors, (b) naturalvariability of soil results from complex interactions between geology, topography, climate as well as soil use(Jenny, 1980; Quine and Zahng, 2002). In addition, variability can also occur as a result of land use andmanagement strategies, making the soil to exhibit marked spatial variability at the macro– and micro– scale(Brejda *et al.*, 2000; Vieira and Paz-Gonzalez, 2003).The general consensus is that the soil qualityconcept should not be limited to soil productivity, but should encompass environmental quality (Karlen *et al.*, 2003).

Thus, assessment of soil quality involves measuring physical, chemical, and biological soil properties and using these measured values to detect changes in soil as a result of land use change or management practices (Adolfo *et al.*, 2007). Though the soil fertility, compatibility and erodibility are the elements of soil quality, the problem of decline in soil fertility endangers the maximum thegrowth in productivity (Katyal, 2003).

Various studies have shown that people are more interested inthe response of soil to management and manipulationOgunkunle (1993). It is thus important to know the use for which piece of land is best suited or the relative suitability of the land for alternative uses. Such knowledge will provide guide in the choice of crops that can be profitably grown and limitations as to the use of the land. Land evaluation is supposed to provide such relevant information. Ogunkunle,(1993) indicated that land evaluation (Land capability classification, land suitability evaluation, fertility capability classification) can tell the farmer the capability of his limitations. Land evaluation may be qualitative, example, fairly suitable, marginally suitable, suitable and not suitable. It may be quantitative, example, crop yield, and beer of wool production, recreation capacity or economic- giving profit and loss for each enterprise on each kind of land (Dent and Young, 1981).

### 2.9.1 Land Evaluation System

Different systems of land evaluation have been developed for different areas by researchers, for example klingibiel and Montgomery (1966) for USA. However the underlying principles same, relevant land use qualities and their critical value for determining suitability classes vary between countries and regions. Therefore, no one method of evaluation is of universal applicability as criteria of relevance to land evaluation are site specific (Ogunkunle 1993). In the past 39 years researchers have developed different systems of land evaluation, while some of these systems have been widely applied, others have limited applications (Young, 1976)

**2.9.1.1 Land Capability Classification (LCC)**

In this method, the various soil mapping units are grouped on the basis of their capability to produce common cultivated crops and pasture plants without deterioration over a long period of time. Under this system, there are eight capability Classes (I-VIII) which rates from the best and most easily farmed land (class 1) to land which has no value for cultivation, grazing and forestry but may be suitable for wildlife, recreation, or watershed (protection Class VIII).

They all fall into two broad groups of land; one suitable for cultivation (Classes I-IV), and one not suitable for cultivation (Classes V-VIII) (Klingibiel and Montgomery, 1966). Capability groups are made at three (3) levels of management; land capability class, subclasses and land capabilityunit (Klingibiel and Montgomery, 1966).

### 2.9.1.2 Land Capability Groupings

The USA soil conservation services uses a uniform system of three levels of soil management; land capability class and subclasses for all soil mapping units, In United States. A third level, land capability unit is also common in some surveys. Soil managementland capability classes are numbered from one to eight. Class I-V can be used cultivation; Classes V- VIII cannot be cultivated in the present state under normal management. Class 1 soil can be usedcontinuously for intensive crop production and minimum attention other than good farming practices. Class II soils have more limitation than class 1soils for intensive crop production such as moderately steep slopes (2-5%). Class III soils have severe limitation and require more special conservation practices than Class II soils to keep them continuously productive. They have shallow soils, steep slopes of about 6-10% or shallow water tables. Class IV soils have severe limitation and need a greater intensity of conservation practices for crop production than Class III soils.

Most of the time these crops should be permanent crops such as pastures, Class V soils are not likely to erode but have other limitations, such as boulders or wetness, which are impractical to connect and this cannot be cultivated. They should be used for pasture, range and wood land or wild life conservation. Class VI soils are suitable for the same uses as class V soils, but they have a greater needs for good management to maintain production because of such limitation as steep slopes or shallow soils. Class VII soils have very severe limitation and require extreme care to protect the soils, even with low intensity use for grazing wildlife or timber. Class VIII soils have such severe limitation (steep slopes, rock lands, swamps, delicate plant cover) that can be wisely used for wildlife, recreation, watersheds and aesthetics.

Soil management land capability subclasses are groups within the eight classes that explain the reasons for the limitation of intensive crop production. Subclasses are designated by lower case letters that follow the Roman numeral of the soil class. The soil capability subclasses recognized are; for example, subclass III

e - erosion hazards is the main limitation

w - wetness

s - shallow, drought or stony

c - climate too cold or too dry

soil management and land capability units are sub divisions of subclasses; within each subclass, the land are suited for essentially the same kind of management and the same kind of conservation treatment is designated as a land capability unit. A land capability unit is essentially in form in all major characteristics that affect its management and conservation. It is the smallest unit recognized in the land capability classification system. Land capability units are designated by ordinary Arabic numerals as II-e, IIe-2, or IIIes-1 etc.

#### 2.9.1.3 Land Suitability Classification/ Evaluation (LSC/E)

It is used to assess the suitability of land for specific kind of use such as rainfed agriculture, livestock production, forestry or land utilization types described in more detail such as rainfed arable farming of groundnut, rice etc.(Dent and Young 1981). It enables the production of suitability map of an area and also enablesthe identification of soil limitation for crop production.FAO (1976), guidelines states that limitations are land characteristics which have an adverse effect on capability. Permanent or severe limitations are those, which cannot easily be changed by minor land improvement.

They include slope angle, soil depth, liability to flooding and climate. Current or temporary or moderate limitations can be removed by land management, examples are soil nutrients, pH and a minor degree of drainage impedance. Land units without any of the abovementioned limitations are rated highly suitable (S1). Land with one moderate limitation is placed in a moderately suitable class (S2). Land with several moderate limitations and not more than one severe limitation are placed in a marginal class (S3). Land with less than three severe limitations that can be corrected with some effort is placed in the currently unsuitable class (N1). If there are more than three severe limitations, lands are considered permanently unsuitable (N2) (Somasiri, 1985)

#### 2.9.1.4Irrigation Capability Classification (ICC)

United State Bureau of Reclamation (USBR, 1953), states that this method is used in determining the extent and degree of suitability of land for irrigation. It assumes that there will be profitable production of the land on a permanent basis under irrigation.

#### 2.9.1.5Stories Index

This method gives values to soil and land properties based on their productivity rating. They are then multiplied to give an index rating. Four factors are considered here for multiplication to give the soil rating. The factors are soil profile factor (A), surface texture factor (F), slope factor (C) and drainage, salinity, alkali, nutrients, acidity erosion and topography factor (X), (Storie, 1978).

#### 2.9.1.6Index of Suitability (IS)

In this method, a model of rating soil productivity is determined from nine soil factors, each factor being rated on a scale of 0-100. The resultant index is obtained by multiplying the actual ratings of the different factors. The factors are soil moisture, base saturation, drainage condition, effective soil depth, texture/structure, soluble salt, organic matter, CEC and mineral reserve (Riquier *et al*, 1970).

#### 2.9.1.6 Fertility Capability Classification (FCC)

This method was developed as an attempt to bridge the gap between the sub- disciplines of soil classification and soil fertility (Sanchez *et al*, 1982). It groups soil according to the kind of problems they present for agronomic management of their chemical and physical properties(Sanchez *et al.*, 1982).Sanchez and Buol (1985) explained that the FCC system has three categorical levels, mainly; type (top soil texture), Sub- strata type (sub soil texture) and condition modifiers. Class designations from each of the three categorical levels are defined below:

**Type:** This refers to the texture of the plow layer or surface whichever is shallower.

S - Sandy topsoil: Loamy sands and sands (by USDA definition)

L - Loamy topsoil: <35% Clay but not loamy sand or sand.

C - Clay topsoil: >35% Clay.

O - Organic soils: >30% O.M to a depth of 50cm or more.

**Substrata Type:** This refers to texture of the sub soil; it is used only when there is a marked texture change from the surface, or if a hard root restricting layer is encountered within 50cm.

S - Sandy subsoil: texture as in type

L - Loamy subsoil: texture as in type

C - Clayey subsoil: texture as in type

R - Rock or other hard root restricting layer.

**Modifiers:** Where more than one criterion is listed as modifier for each sample, only one need to be met. The criterion listed first is the most desirable one, should be used if data are available. Subsequent criteria are presented and used where data are limiting.

g = (gley): soil or mottles <2 Chroma within 60cm of the soil surface and below all A horizons, or soil saturated with water for 60 days in most years.

d = (dry): ustic, aridic or xeric soil moisture regimes (subsoil dry > 90 cumulative days per year within 20-60cm depth).

e = (low cation exchange capacity): applies only to surface layer or surface 20cm, whichever is shallower: CEC< 4meq/100g soil by bases + KCL extractable Al (effective CEC), or CEC < 7meq/100g soil by ∑ cations + Al +H at pH 8.2.

a = (aluminum toxicity): > 60% Al saturation on CEC by ∑ cations at pH 7 within 50cm of soil surface, pH< 5.0 in 1:2.5 $H_2O$within 50cm, except in organic soils where pH must be less than 4.7

h = (acid): 10-60% Al-saturation of the effective CEC within 50cm of soil surface, or pH in 1:1 $H_20$between 5.0 and 6.0.

i = (high P-fixation by iron): % free $Fe2O_3$/% clay>0.15 and more than 35%clay, or hues of 7.5YR or redder and granularstructure. This modifier is used only in claytypes; it applies only to plow- layer or surface 20cm of soil surface whichever is shallower.

x = (x-ray amorphous): pH>10 on 1N NaF, or positive to field NaF test, or other indirect evidences of allophane dominance in clay fraction.

v = (vertisols): very strictly plastic clay: > 35% clay and 50% of 2:1 expanding clays, or severe topsoil shrinking and swelling.

k = (low k reserves): ,100% weatherable minerals in silt and sand fraction within 50cm of the soil surface, orexchangeable k,0.20cmol/kg, or k,2%of 0.20cmol/kg, or k,2% of bases: 10cmol/kg.

b = (basic reaction): free $CaCO_3$within50cm of soil surface (effervescence with HCl), or pH>7.3

s = (salinity) :> 4mhos/cm EC within lm of the surface.

n = ( natric) :> 15% Na-saturation CEC within 50cm of the surface.

c = (clay): pH in 1:1 $H_2O$ is <3.6 after drying and jarosite mottles with hues of 2.5Y or yellower and chromas 6 or more are present within 60cm of the soil surface.

l= (gravel): a prime (' ) denotes 15-35% gravel or coarser (>2mm) particles by volume to any; type substrata type texture two prime marks (" ) denotes >35% gravel or coarser (>2mm) particles by volume

f = (low base saturation): % base saturation<50%.

% = (slope): where it is desirable to show slope with the FCC, the slope range percentages can be placed in parenthesis after the last condition modifier (e.g. sb 1-6)

The FCC units lists the type and substrata type (if present) in capital letters and the modifiers in low case letters. Theabsence of modifiers suggests no major fertility limitations other than nitrogen deficiency.

# CHAPTER THREE

## Materials and Methods

### 3.1 Study Area

The research was carried out inOguta Imo state, South-eastern Nigeria.Its geographical coordinates lies withinLatitudes 5º 05' to 5º 50’ 24’’ North and Longitudes 6º 15' to 6º 55’33" East, and elevation of 122m,Nwadiaro (1987).It is within the equatorial rainforest region though the archetype forests around the lake have been replaced by oil palm(*Eliasis guineensis*)grooves and agroforestry species such as bush mango *(Irvinga sp)* and plantain (Musa *sp)*. Oguta is known or its high rainfall of about 2, 500mm/yr. The Soils were derived from Coastal Plain Sands (Benin formation) of the Oligocene-Miocene geologic era. Due to negative human influence, the land has lost its thick vegetation cover and is exposed to a high rate of erosion. The study site covers about 1500 hectares of land.

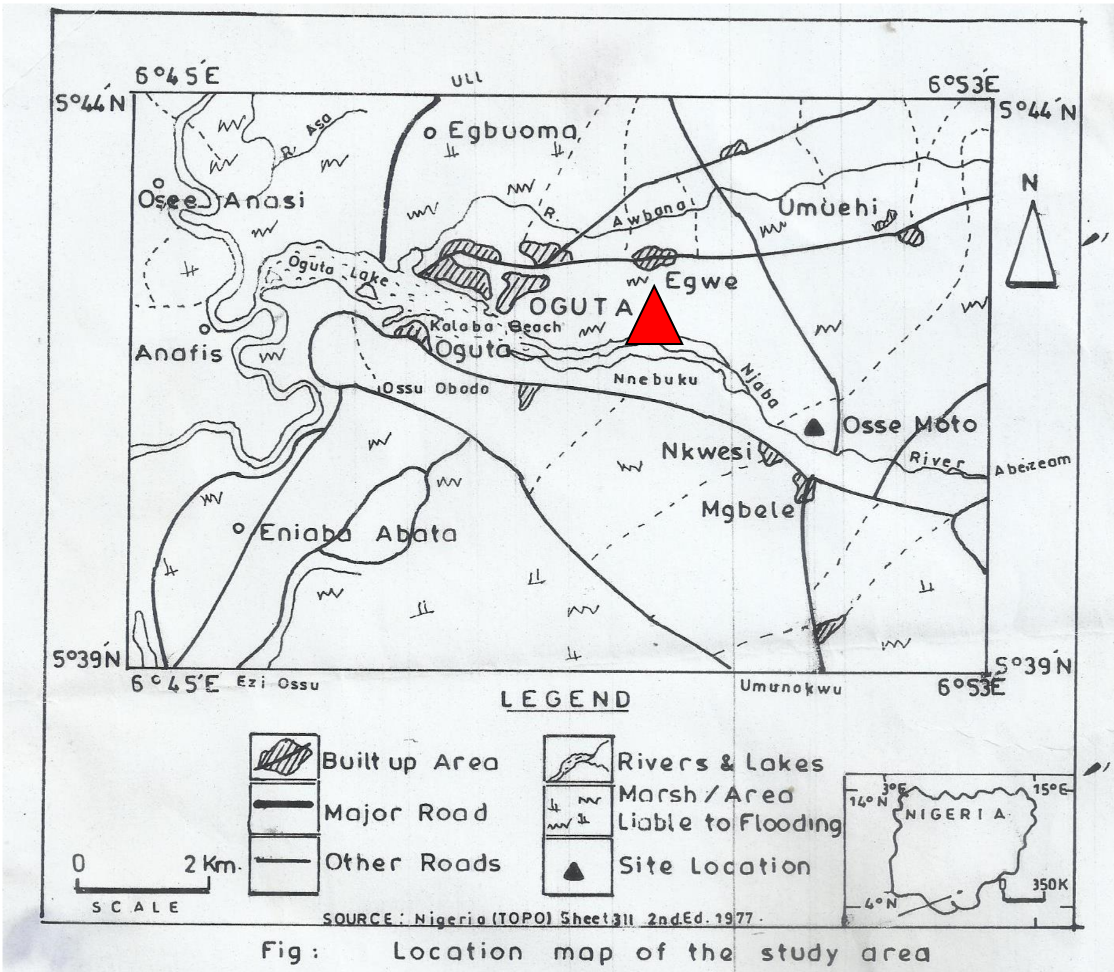



**Fig 3.1 Location Map Showing the Study Area**

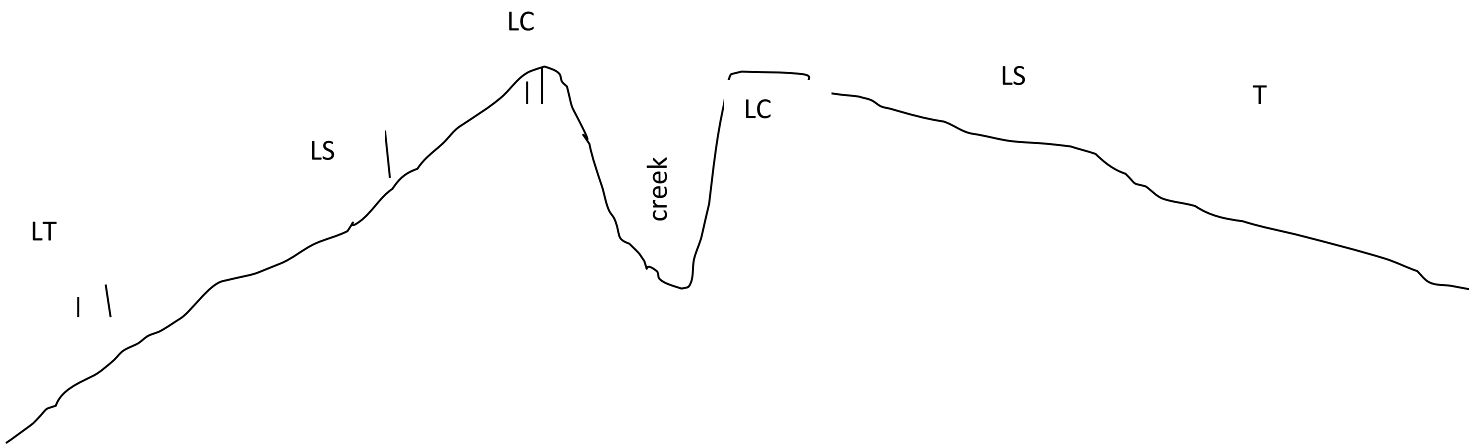
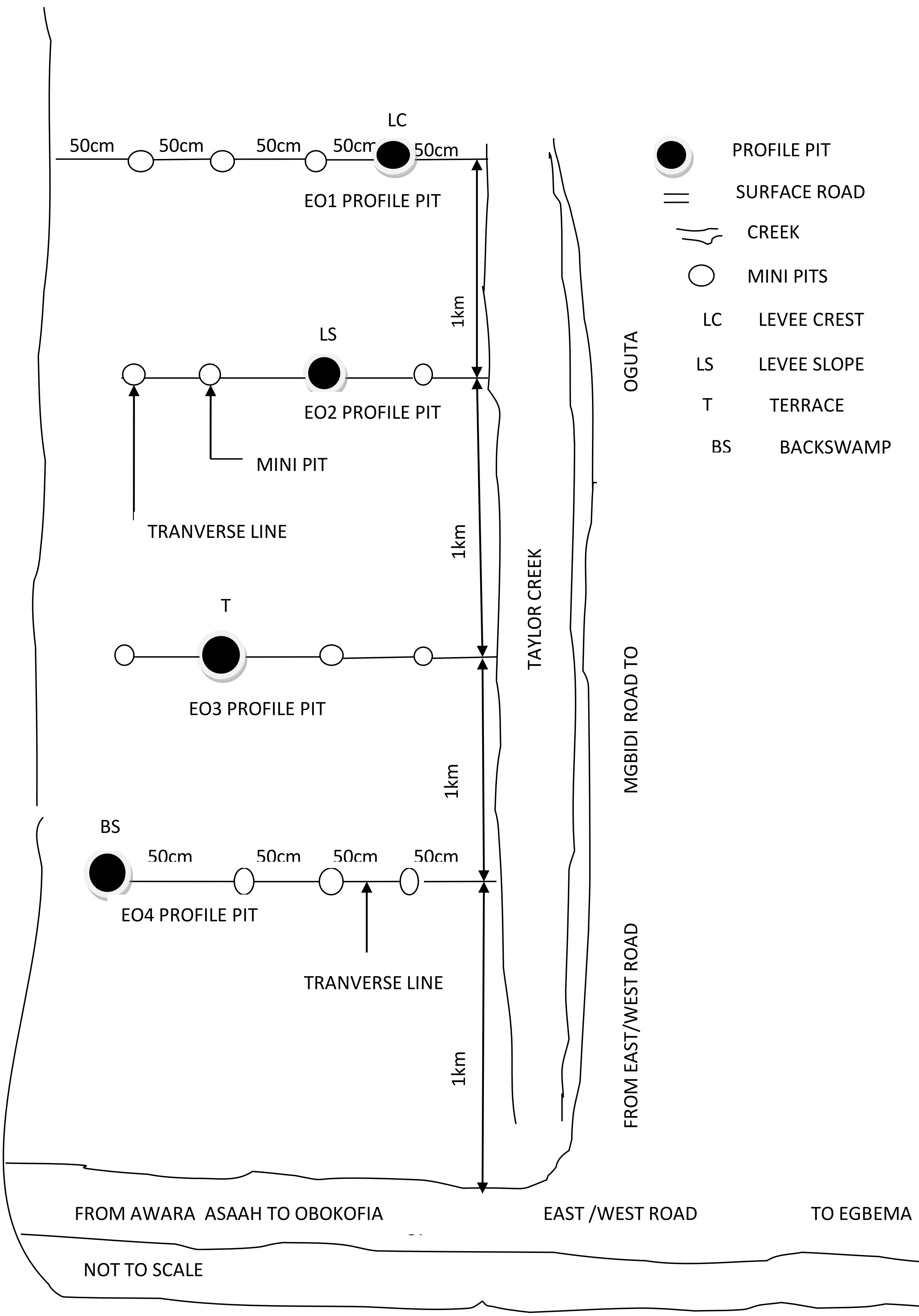



**Figure 3.2Cross Sectional Diagram Showing Geomorphic Units**



LC
50cm
50cm
50cm
50cm
50cm
EO1 PROFILE PIT
PROFILE PIT
SURFACE ROAD
CREEK
MINI PITS
LC LEVEE CREST
LS LEVEE SLOPE
T TERRACE
BS BACKSWAMP
1km
LS
EO2 PROFILE PIT
MINI PIT
TRANVERSE LINE
OGUTA
1km
TAYLOR CREEK
T
EO3 PROFILE PIT
MGBIDI ROAD TO
1km
BS
50cm
50cm
50cm
50cm
EO4 PROFILE PIT
TRANVERSE LINE
FROM EAST/WEST ROAD
1km
FROM AWARA ASAAH TO OBOKOFIA
EAST /WEST ROAD
TO EGBEMA
NOT TO SCALE

### 3.1.2 Geology and Geomorphology of the Study Area

Recent sediment of the Benin formation on which floodplain alluvium have been deposited, underlie the site. Farag *et al* (2008). The sedimentary rocks are generally poorly consolidated and prone to gullying. The Benin formations consist of alternating shale, sandy shale, clayey sandstone, limestone, and lignite bands. While the western part is low lying and generally featureless, the eastern and northern portion are highly undulating topography interspersed with flat plains. The parts are marked by spectacular gullies, with the main river, Njaba laden with sediment. The alluvium consists of argillaceous particles while the Benin Formation consists of poorly sorted, cross-bedded friable sands with minor intercalations of clay. (Onweremadu 2006) It is characterize by wooded back swamps and fresh water swamps. The widening of the delta, the constantly decreasing slope gradient of the bed of Niger river and the resultant decreasing stream velocities which has resulted to alluvial deposition along the creek which is linked to Utu River on its North, Njaba River on its South-west. The water courses have well developed levees. There is also an abandoned channel and backswamps consisting of unconsolidated clays and silts derived from over- bank flows.

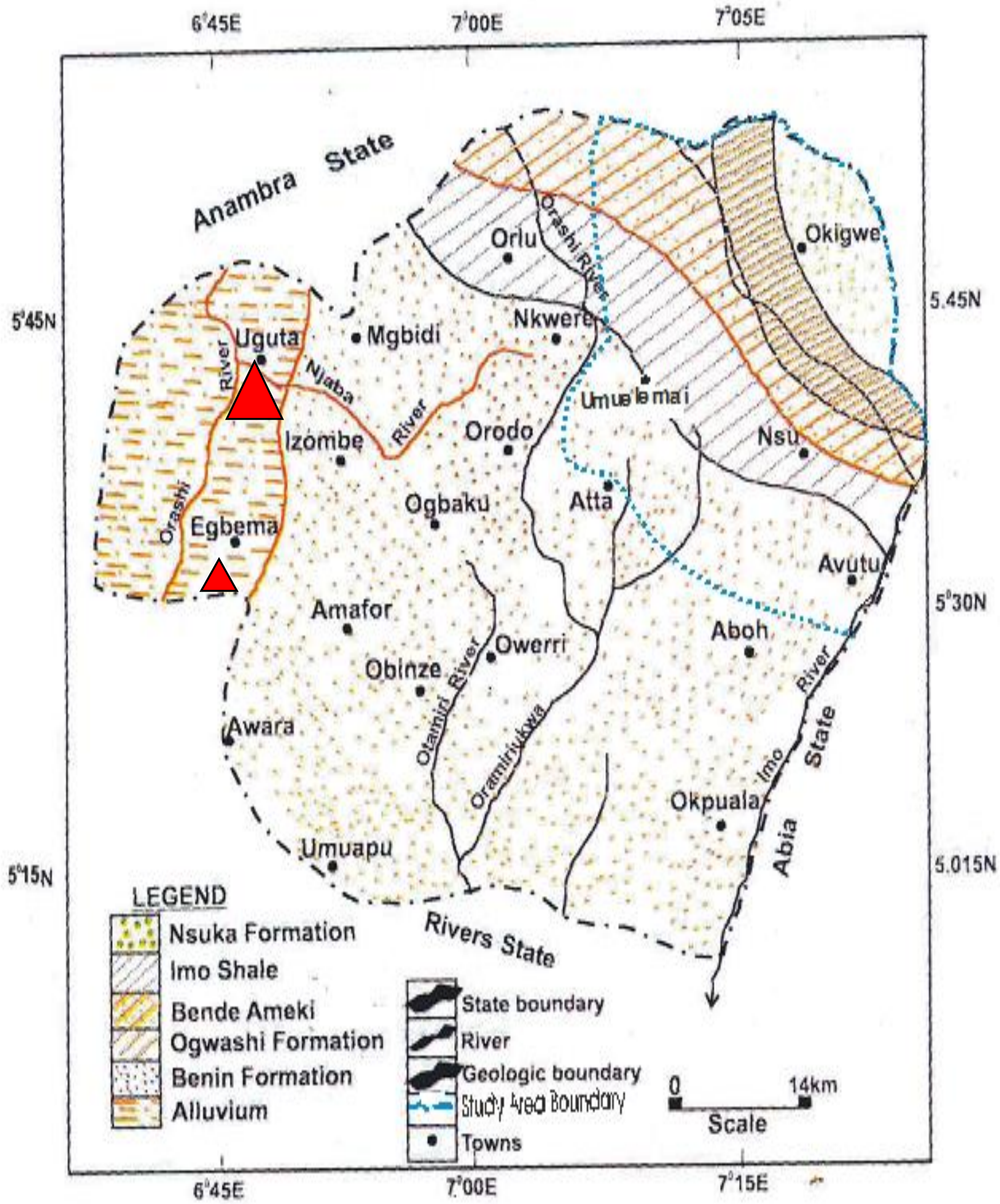



**Fig 3.4Geological Map of the Area Adopted from Nwosu *et al*(2011)**

The bank faces show layers of sands and clays with the sand layers frequently sandwiched between a loamy to clayey, material and a nearly submerged clay layer.

### 3.1.3Climate

The climate according to Koppen's classification is**Af**(i.e. humid tropical rain forest), with a bimodal distributionof short dryseason extending from December to February and a long rainy season during the remainder of the year with the peak in September. The period between July and August is characterized byovercast skies and milder temperatures (mean: $25^0$C). Mean temperatures range from25ºC to 28ºC (April),the dry season is dominated by dusty, Harmattan winds extending from December to February. Table 3.1 shows mean monthly and annual rainfall in Oguta 2013

Table 3.1 Mean Monthly and Annual Rainfall in Oguta (2013)

| Months | Amount of Rainfall (mm) | Days |
|---|---|---|
| January | 102.4 | 1 |
| February | 54.6 | 1 |
| March | 247.5 | 4 |
| April | 410.2 | 5 |
| May | 617.3 | 11 |
| June | 308.8 | 8 |
| July | 399.7 | 12 |
| August | 777.1 | 12 |
| September | 623.4 | 13 |
| October | 738.5 | 11 |
| November | 331.1 | 0 |
| December | 0.00 | - |
| **Total** | **4610.6** | **78** |
| **Mean** | **384.2** | **6.42** |

Source: Ministry of Agriculture and Natural Resources Engineering Department Imo State Nigeria.

### 3.1.4 Vegetation

The archetype vegetation of the area is the rain forest, but this has beenreduced to a mosaic of small plots of field crops likecassava*Manihot sp*), yams (*Dioscorea esculeta*), cocoyams (*Colocasia esculenta)*,vegetables and agro-forestry (oil palms, *Irvingia* sp., *Cola* sp., *Musa* sp.). Whereasoil palm is grown in grooves or plantations, other cropsare grown around homesteads.Except in the main urban communities, settlements are dispersed and fieldplots and agro-forestry surround the homesteads.

### 3.1.5 Hydrology and Drainage

Oguta houses one of the largest naturallakes in Southeastern Nigeria,located in a natural depression within the extended East bank flood plain of the River Nigerdownstream of Onitsha. The lake is source of municipal and domestic water for Oguta Community. It is also the receptacle of urban sewage from Oguta and environs, and a trap for sediment. Egwe - Obana River has its source from Oguta Lake. It enters via an estuary into Oguta Lake.The small town Ndiobinikpais locatedwithin the study area. The alluvium underlying the area is a good aquifer that is annually recharged by rainfall and flood waters. The general morphology of the various rivers and creeks lead to the meandering of the waterways, (Wenibo, 2012). This meandering and river discharge system causes bank erosion and local sedimentation (Fubara, 2005). Basically, there is a varied difference in water discharge between the dry and wet seasons; which causes flood and accelerate the stream bank erosion rate.

The period between July and August experiences increase in water level of the creeks which is largely occasioned by high run-off in the catchment area and subsequently the river invading its surrounding. The flooding which peaks in October and recordsin November submerges land up to two to three meters in the basins and backswamps.

### 3.1.6 Socio-economic activities

The major occupation of the people is fishing, water transport, sand dredging, and tourism. Other social-economic activities include farming (cassava, yams, maize, sugarcane, legumes and vegetables), agroforestry, limited poultry, cattle, sheep and goat rearing, piggery, cottage industry.

## Field Studies

### 3.1.7 Geomorphic Units:

During a reconnaissance visit, geomorphic units were identified. These included Levee crest, Levee slope,Terrace and Backswamps.

**Levee Crest Soils**

The soils occupy the highest position of the land in Oguta and were located near the creek. Their heights above sea level made them the least flooded soils. The levee crest was where most town and villages were located. Levee crest located in upper Delta were well above sea level (about 8m or more) for most of the year with depth to ground water table of 3 to 4m. Some levee crest soils were flooded at the peak of heavy floods to a depth of 1to1.5m for more than 2weeks. They are well drained soils.

**Levee Slope**

These soils occur at the back slope of the levee crest between levee crest and terrace. Some of these soils were submerged at the peak ofheavy flood up to 2m or more. Though not deeply flooded, these soils remain very wet in the rainy season because of the inadequate natural drainage channels. They were moderately well drained soils.

**Terrace**

These soils were the low-lying stretches of land bounded by levees. They were poorly drained though better drained than the backswamp soils. They were flooded for 3 to 4 months during the peak of heavy flood.

**Backswamps**

These soils were usually flooded for more than 3or4 months in a year; they were usually poorly or very poorly drained. They had high water table compared to the soils of the other mapping units. They were located at lower position than all the above mentioned mapping units.

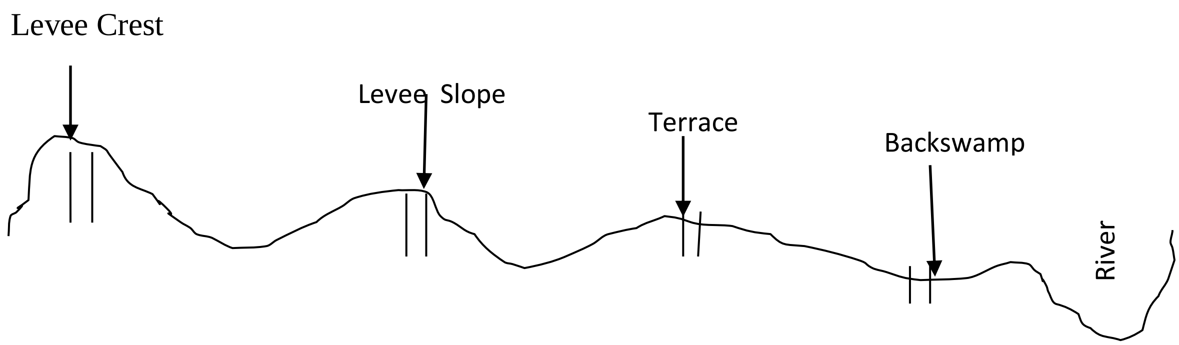



**Figure 3.5 Toposequence showing geomorphic Units**

### 3.1.8Present Land Use and Human Activities

Ecology, soil factors and socio-economic factors are the major determinants of land use pattern in the area. Soils of the levees and foot slope were used locally in traditional agriculture.Mixed cropping is freely practiced. Banana, plantain, cassava, yam, Cocoyam, maize, and pepper are the main crops grown.

Cultivation of crops is done for one or two years, thereafter, the land is allowed to fallow for five years. Preparation of the land is normally slashing and bush burning or by slashing and removal of the debris after which the soil is manually tilled with hand hoe.

The backswamps are not cultivated because of their attendant problem of flooding. However, cassava cultivation and palm plantation is increasingly gaining popularity in the backswamps of Oguta. During the floods, a lot of fishing activities are carried out in the backswamps and terraces. Lumbering is also a form of human activity in the study area.

## 3.2 Sampling Procedure

A reconnaissance visit was carried out before the commencement of field operations. In addition to profile pit sampling, random surface soil sampling was carried out in the study site.Sixteen surface soil samples (0-20 cm) were collected, four from each geomorphic unit using an auger. This gave a total ofthirty three soil samples; seventeen

(17) samples from the four profile pits inclusive.These were chosen to represent the main morphological variations and to represent the main mapping units of soils ofOguta Imo state Southeastern Nigeria. Surface soil samples of 0-20cm were collected because agronomic soil samples are usually taken from 0-15 or0-20cm depth where a large proportion of the active root zone is. Also, surface runoff in most cases interacts with only the top few cm of soil.

Munsell colour chart was used to determine the soil colour and core samplers were also used to collect samples in the field.A standard procedure was used in profile description (FAO, 2006).Soil morphological characteristics such as soil colour, structure, consistence, roots development, faunal activity, boundary and effective soil depth were determined.Traverse lines of 200 meters wereconstructed at 1000metersintervals starting from Mgbidi Road going to Oguta. About 1500 meters was covered. Along each traverse line at 1000meters point, soil observation was carried out at interval of 50 meters with an Elderman auger. After four observation points, on each traverse line, a profile (pedon)was sunkon the levee crest (EO1), on 1000meters traverse, another was sunk. On the levee slope (EO1),and another profile pit was sunk on the terrace (EO3) while the other profile pit was sunk on the backswamp (EO4). Each pit dimension was 2.0m x 1m x 2m. The 2m depth was attained, except where shallower water- table posed as hindrance. Soil sampleswere collected from identified genetic horizons. Undisturbed core samples were also collected with core samplers for bulk density determination andother selected physco-chemical properties of the soil. The samples collected were properly labeled, bagged in polyethene bags and later, air-dried, for 7days at room temperature, crushed, sieved with 2mm mesh sieve. All sieved samples were stored in well labeled polyethene bags and sent to the laboratory forlaboratory analysis.

All the soil profiles were geo-referenced using a handheld Global Positioning System (GPS) Receiver. The morphological features observed in the field were, colour, mottles, structure, texture, consistence, presence of faeces, pores, nature of horizon boundary, root, and weatherable minerals etc. Attention was given to colour and mottles in describing the morphological properties of the soils because they tend to bring out contrasting features of the soils in the geomorphic units observed in the study area

## 3.3 Laboratory Analysis

The samples wereair dried, sieved using 2mm meshand analyzed in the laboratory for the Physco-chemical properties neededcharacterization for the, classification, and evaluationof thesoils of the four geomorphic surfaces.

**3.3.1Bulk Density:** Bulk density wasdetermined by core sampler method according to the procedure of Grossman and Reinsch (2002).

Bulk Density = $\frac{Mass\ of\ oven\ dry\ soil}{Volume\ of\ core\ sampler}$

It was expressed in $mg/m^3$ (Brady and Weil, 2002)

**3.3.2 Particle Size Distribution:**It was determined by Bouyoucous Hydrometer method according to the procedure of Gee and Or (2002) where sodium hexametaphosphate (calgon) solution wasused as a dispersing agent.

**3.3.3Total Porosity:** It was calculated from the result of bulk density and particle density.

$$Porosity, P = \left(1 - \frac{Db}{Dp} x \frac{100}{1}\right) (\ Brady\ and\ Weil, 2002).$$

Where P = Porosity

Db = Bulk density ($g/cm^3$)

Dp = Particle density (assumed to be 2.65g/cm$^3$)

**3.3.4Moisture Content:** It was determined by gravimetric method.

$$\%MC = \frac{W^2 - W^3}{W^3 - W^1} x \frac{100}{1}$$

Where % MC = percentage moisture content

$W_1$ = weight of empty can

$W_2$ = Weight of air-dried soil plus moisture can

$W_3$ = Weight of oven-dried soil plus moisture can

(Brandy and Weil, 2002)

**3.3.5 Exchangeable Sodium Percentage (ESP)**

The exchangeable sodium percentage (ESP) was calculated as

$$ESP = \frac{Exch\ Na}{ECEC} x \frac{100}{1}$$

(Brady and Weil, 2002)

**3.3.6Percentage Base Saturation (%BS):**It was calculated as

%BS = $\frac{TEB}{ECEC} x \frac{100}{1}$

Where %BS = Percentage base saturation

TEB = Total exchangeable basic cations

ECEC = Effective Cation Exchange Capacity

**3.3.7Aluminum Saturation (Al Sat.):**It was calculated as

$$\frac{Exch.Al}{ECEC} x \frac{100}{1}$$

Where Exch. Al = Exchangeable Aluminum

ECEC= Effective cation exchange capacity

**3.3.8Carbon/Nitrogen Ratio:** This was calculated as$\frac{OC}{TN}$

Where C/N ratio= Carbon Nitrogenratio

OC =Organic carbon

TN = Total nitrogen

**3.3.9Soil Reaction(pH):**Itwas measured in a suspension as soil/water ratio of 1:2:5 and 1:1 soil for $H_2O$ and in KCl respectively Standardization of pH meter was done using buffer solutions of pH 7.0 (water) and 4.0 (in KCl) and determined using glass electrode pH meter as described by Hendershot *et al* (1993).

**3.3.10Organic Carbon:**It was determined by the wet oxidation procedure (Nelson and Sommers, 1982).

**3.3.11Total Nitrogen:** It was determined using the modified micro kjeldhal method according to the procedure of Bremner and Mulvaney (1982).

**3.3.12Available Phosphorus:**It was done using the molybdenum blue color Bray II method (Olsen and Sommers, 1982).In which P was extracted by adding 40.0ML of 0.5N$NaHCO_3$ as extracting solution, including a method of blank and standard quality control samples. The extracting vessels were placed on oscillating mechanical shaker for 30minutes after which the suspension was immediately filtered- within 1 minute. 3.0mL of aliquot of standard was introduced with pipette into a 2.5cm matching spectrometer tube, 9.0mL of deionized water was added inclusive was3.0ml of reagent B (molybdate reagent).The absorbance was read after 10 minutes using UV spectrophotometer and the concentration of p was calculated from a standard curve and recorded.

**3.3.13Exchangeable Basic Cations:** It was determined with Ammonium Acetate ($NH_4OAc$) leachate of the soil(Thomas, 1982). Exchangeable calcium and magnesium was determined by the EDTA

(Ethylene diamine tetra-acetic Acid) versenate titration method where Ca and Mg indicator (EBT) complex was dissociated by titrating with standard EDTA solution. While exchangeable sodium and potassium wasdetermined by flame photometer method in which atoms of the elements, K, and Na was exited in the flame photometer and the light intensity emitted was converted into electrical energy shown in the meter read out as figures (Jackson, 1962).

**3.3.14Exchangeable Acidity (Al + H):** It was determined by titration as described by (Juo1979). It was extracted with one normal potassium chloride solution. The exchangeable hydrogen was obtained by subtracting exchangeable aluminum from the exchangeable acidity. Exchangeable acidity (Al + H) - Exchangeable Al =Exchangeable H (Juo, 1979)

**3.3.15Effective Cation Exchange Capacity (ECEC):** It was derived by the summation of the total exchangeable bases (TEB) and exchangeable acidity (Al + H) (Brady and Weil, 2002).

## 3.4Soil Classification

Based on the results obtained from the laboratory analyses and field morphological properties, the soils were classified according to the

Soil Taxonomy (Soil Survey Staff, 2010) guidelines and with FAO/UNESCO/(FAO 2006).

The soils were described in particular order based on the type of diagnostic horizons identified in the pedons. The presence or absence of properties associated with wetness and soils with common similarities (i.e. in kind), arrangement and degree of expression of horizons. Soils were placed in a particular class based on whether they represent the central concepts of group, intergrades or transitional forms.

### 3.4.1Land Evaluation Techniques

Three land evaluation systems were used to assess the potentials of the soils for various agricultural purposes. These systems were Land Capability Classification, Fertility Capability Classification and Land Suitability Evaluation.

### 3.4.2 Land Capability Classification (LCC)

The system of Klingebiel and Montgomery (1966) was used as a basis for classifying the soils in the various mapping units throughout the study area. The soils in the various mapping units were grouped into the various capability classes and subclasses as outlined by the system. Due to the aberrant kinds of limitation encountered in the soils of the study area, which might affect crop performance differently, subclass designations were modified. Rather than using erosion (e), excess water (w), soil root zone limitations and climate (c),as subclass designations; angle of slope (a), soil textures (t), wetness (w), and nutrient holding capacity (n) were used.

### 3.4.3 Fertility Capability Classification (FCC)

Sanchez *et al*, (1982) version of FCC was used which consist of three categorical levels: "Type" sub strata type and "modifiers". Thedetails of the criteria for FCC system are shown in table. Class designations from the three categorical levels were combined to form FCC unit. The unit lists the type and substrata type (if present) in capital letters, and the modifiers in lower case letters e.g. Sehk means uniformity sandy soil in which its capability is conditioned by low CEC (e), acidic (pH) reaction (h) and (k) - deficiency (K). Thus the soils were classified according to whether a characteristic was present or not. In this study, the FCC units of the four pedons were determined based on soil profile characteristics.

The "Type" of the mapping units was bent on whether the top soil has clay less than or greater than 35%. If topsoil is < 35% clay, the "Type" was determined as L (loamy soil) but if it is > 35% clay, the "Type" was determined as C. (clayey soil). The substrata "Type "which signifies the subsoil was determined the same way as the "Type". The "Modifiers" were determined from the soil profile characteristics within 0-50 or 60cm from the top of the soil.

### 3.4.4 Land Suitability Classification/ Evaluation

Land suitability classification done was based on the FAO (1976): Berhanu (1980): Sys (1985): Kosuowei (2008). Pedons were placed in suitability classes by matching their characteristics (Table 3.2) with land use requirements or rating of land qualities representing soil conditions for the various crops (Table 3.3, 3.43.5, 3.6)

**Table 3.2: Rating of Land Qualities Representing Soil Conditions (**Source: Berhanu 1980)

| Land Quality | Land Characteristics | Wt | High (S) | Moderate (S2) | Low (S3) | Very Low (N1) |
|---|---|---|---|---|---|---|
| Land Quality Score | | 4 | 3 | 2 | 1 | 0 |
| 1. Nutrient Status | Organic Carbon % | 1 | >3.0 | 1.5-3.0 | 0.5-1.5 | <0.5 |
| | Total Nitrogen % | 1 | >0.25 | 0.12-0.25 | 0.01-0.12 | <0.01 |
| | Available P (Bray) Ppm | 1 | >25 | 15-25 | 15-10 | <10 |
| | Available K Meq/100g | 1 | >0.6 | 0.3-0.6 | 0.2-0.3 | <0.2 |
| | pH ($H_2O$ 1:1) | 1 | 6.5-7.2 | 5.5-6.5 | 4.5-5.5 | <4.5 |
| | | | | 7.2-8.0 | 8.0-8.5 | >8.5 |
| | CEC Meq/100g | 2 | >35 | 20-35 | 10-20 | <10 |
| | Base Saturation% | 1 | >75 | 50-75 | 25-50 | <25 |
| 2. Workability | Soil Consistence | | | | | |
| | -dry | 2 | Soft | Loose, Hard | Very hard | extremely hard |
| | -Moist | 2 | Friable | Slightly hard | very firm | extremely firm |
| | -Wet | 2 | Non Sticky | Loose, Firm | Sticky, Plastic | v. sticky |
| | | | Non Plastic | Slightly | v. plasticSticky | SlightlyPlastic |
| 3. Drainage | Drainage class | 3 | well | Mod. well | Imperfect, Poor | Excessive, v. poor |
| | Porosity/Abund/cm2 | 2 | 200 | 100-200 | 50-100 | <50 |
| | Pore-size, mm | 2 | 2.0-5.0 | 0.1-2.20 | >5.0 | <0.1 |
| | Permeability cm/hr | 3 | 2-6 | 6-13 | 13-25 | <25 |
| | infiltration mm/hr | 2 | >2.0 | 0.5-2.0 | 0.1-0.5 | <0.1 |
| | Ground water table cm | 3 | >200 | 100-200 | 50-100 | <50 |
| 4. Available $H_2O$ | | 5 | | | | |
| | Texture Class | 3 | L", CL | SL, SCL | LS, SC, C, Si C, Si | S |
| | Porosity/Abund/$cm^2$ | 2 | 200 | SiCL, Si L | 50-100 | <50 |
| | Pore size, mm | 2 | 2.0-5.0 | 0.1-2.0 | >5.0 | 0.1 |
| 5. Rooting Depth | | 4 | | | | |
| | Soil Depth cm | 3 | >50 | 20-50 | 10-20 | <10 |
| | Class | 2 | 0 | 1 | 2, 3 | 4.5 |
| | Rockiness Class | 2 | 0 | 1 | 2 | 3, 4, 5 |
| | Index of soil condition | 2 | 75 | 50 | 25 | 0 |

Key

| | | | |
|---|---|---|---|
| SCL= Sandy Clay Loam | LS = Loamy Sand | L = Loam | SiL = Silty Loam |
| SL= Sandy Loam | SiCL= Silt Clay Loam | CL= Clay Loam | SiC = Silty Clay |

Si= Silt SC = Sandy Clay C =Clay S = Sand

**Table 3.3: Ratings of Land Qualities Representing Soil Conditions for Wetland or Swamp Rice Production(**Modified from Berhanu;1980 Sand Sys (1985)

| Land Quality | Land Characteristics | Wt | High (S) | Moderate (S2) | Low (S3) | Very Low (N1) |
|---|---|---|---|---|---|---|
| Land Quality Score | | 4 | 3 | 2 | 1 | 0 |
| 1. Fertility Status | Organic Carbon % | 1 | 2-3 | 1-2 | 3-4 | >4 |
| | Total Nitrogen % | 1 | >0.2 | 0.1-0.2 | 0.05-0.1 | <0.05 |
| | Available P (Bray 2) Ppm | 1 | >20 | 15-20 | 10-15 | <10 |
| | Exch. K Cmol/kg | 1 | >0.2 | 0.1-0.2 | <0.1 | <0.1 |
| | Exch. Ca. cmol/kg | 1 | 10-15 | 5-10 | 1-5 | <1 |
| | pH ($H_2O$ 1:1) | 1 | 5.5-7.5 | 5.2-5.5 | ≤5.5-≥8.2 | ≥5.2-≥8.2 |
| | CEC, cmol/kg | 2 | >16 | 10-16 | 5-10 | <5 |
| | Base Saturation% | 1 | >75 | 50-75 | 25-50 | <25 |
| 2. Workability | | | | | | |
| | Soil Consistence | | | | | |
| | -Moist | 2 | Extremely Firm | very firm | Slightly hard | Friable |
| | -Wet | 2 | Very Sticky | | Loose Firm | |
| | | | Very plastic | sticky Plastic | Slightly Sticky | n sticky |
| | | | | | Slightly plastic | n plastic |
| 3. Toxicity | | 6 | | | | |
| | ESP% | 2 | 0-5.0 | 5.0-8.0 | 8.0-10 | >10 |
| | Porosity/Abund/cm2 | 2 | <0.75 | 0.75-1.0 | 1.0-1.25 | <1.25 |
| 4. Wetness | | 6 | | | | |
| | Drainage Class | 3 | VPD | PD | MWD | WD |
| | Flood Duration (months) | 2 | >4 | 3-4 | 2-3 | <2 |
| | Groundwater table, cm | 3 | <50 | 50-100 | 100-200 | >200 |
| 5. Climate | | 5 | | | | |
| | Annual Rainfall (mm) | 2 | >400 | 1200-1400 | 950-1100 | 850-900 |
| 6. Soil Physical Characteristics | | 4 | | | | |
| | Texture Class | 3 | SC, C, SiC, S | SCL, SICL, SiL, CL | L, SL | S,LS |
| | Soil Depth(cm) | 3 | >50 | 20-50 | 10-20 | >10 |
| | Clay % | 2 | >50-25 | 25-15 | 15-5 | 5-25 |
| | Ideal Index of soil condition for wetland rice production | | >75 | 50-75 | 20-50 | <20 |

**KEY**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| VPD | = Very Poorly Drained | PD | = Poorly Drained | MWD | = Moderately Well Drained | WD | = Well Drained |
| SCL | = Sandy Clay Loam | LS | = Loamy Sand | L | = Loam | SiL | = Silty Loam |
| SL | = Sandy Loam | SiCL | = Silty Clay Loam | CL | = Clay Loam | SiC | = Silty Clay |

Si = Silt SC = Sandy Clay C = Clay S = Sand
ESP = Exchangeable Sodium Percentage

**Table 3.4: Rating of Land Qualities Representing Soil Conditions for Cassava Production (**Source: Kosuowei 2008)

| Land Quality | Land Characteristics | Wt | High (S) | Moderate (S2) | Low (S3) | Very Low (N1) |
|---|---|---|---|---|---|---|
| Land Quality Score | | 4 | 3 | 2 | 1 | 0 |
| 1. Nutrient Status | Organic Carbon % | 1 | >3.0 | 1.5-3.0 | 0.5-1.5 | <0.5 |
| | Total Nitrogen % | 1 | >0.01-0.1 | 0.12-0.12 | 0.01-0.12 | <0.01 |
| | Available P (Bray) Ppm | 1 | >25 | 15-25 | 15-0.3 | <10 |
| | Available K Meq/100g | 1 | >0.6 | 0.3-0.6 | 0.2-0.3 | <0.2 |
| | pH ($H_2O$ 1:1) | 1 | 6.5-7.2 | 5.5-6.5, 7.2-8.0 | 4.5-5.8, 0-8.5 | <4.5, >8.5 |
| | CEC Meq/100g | 2 | >35 | 20-35 | 10-20 | <10 |
| | Base Saturation% | 1 | >75 | 50-75 | 25-50 | <25 |
| 2. Workability | Soil Consistence | 6 | | | | |
| | -dry | 2 | Soft | Loose, Hard | Very hard<br>Extremely hard | |
| | -Moist | 2 | Friable | Slightly hard, Loose, Firm | very firm<br>Extremely firm | |
| | -Wet | 2 | Non Sticky<br>Non Plastic | Slightly Sticky<br>Slightly Plastic | Sticky, Plastic | v. sticky<br>v. plasticSticky |
| 3. Drainage | | 6 | | | | |
| | Drainage class | 3 | well | Mod. well somewhat | Imperfect, Poor | Excessive, v. p |
| | Porosity/Abund/cm2 | 2 | 200 | 100-200 | 50-100 | <50 |
| | Ground water table cm | 3 | >200 | 100-200 | 50-100 | <50 |
| 4. Available $H_2O$ | | 5 | | | | |
| | Texture Class | 3 | L", CL | SL, SCL, SiCL, SiL | SC, C, SiC, Si | S, LS |
| | Porosity/Abund/cm2 | 2 | 200 | 100-200 | 50-100 | <50 |
| 5. Rooting Depth | | 4 | | | | |
| | Soil Depth cm | 3 | >50 | 20-50 | 10-20 | <10 |
| | Index of soil condition | | | | | |
| land quality Index range | >80 | 40-80 | 20-40 | >20 >80 | 40-80 | 20-40 <20 |

**Key**
SCL= Sandy Clay Loam LS = Loamy Sand L = Loam SiL = Silty Loam

| | | | |
|---|---|---|---|
| SL= Sandy Loam | SiCL= Silt Clay Loam | CL= Clay Loam | SiC = Silty Clay |
| Si= Silt | SC = Sandy Clay | Clay | S = Sand |

**Table 3.5: Rating of Land Qualities Representing Soil Conditions for Maize Production;** Modified from Berhanu: (1980) and Sys (1985)

| Land Quality | Land Characteristics | Wt | High (S1) | Moderate (S2) | Low (S3) | Very Low (N1) |
|---|---|---|---|---|---|---|
| Land Quality Score | | 4 | 3 | 2 | 1 | 0 |
| 1. Fertility Status | Organic matter % | 1 | 1.2.2 | 1.0-1.2 | 0.8-1.0 | 0.6-0.8 |
| | Total Nitrogen % | 1 | >0.2 | 0.1-0.2 | 0.05-0.1 | <0.05 |
| | Available P (Bray 2) Ppm | 1 | >20 | 15-20 | 10-15 | <10 |
| | Exch. K Cmol/kg | 1 | >0.2 | 0.1-0.2 | <0.1 | <0.1 |
| | Exch. Ca. cmol/kg | 1 | 10-15 | 5-10 | 1-5 | <1 |
| | pH ($H_2O$ 1:1) | 1 | 5.5-7.5 | 5.2-5.5 | ≤5.5-≥8.2 | ≥5.2-≥8.2 |
| | CEC, cmol/kg | 2 | 16-24 | <16(-) | <16(+) | <10 |
| | Base Saturation% | 1 | 35-50 | 20-35 | 15-20 | <15 |
| 2. Workability | Soil Consistence | 6 | | | | |
| | -dry | 2 | Soft | Loose, Hard | Very hard | Extremely hard |
| | -Moist | 2 | Friable | Slightly hard, | Loose, Firm Extremely firm | very firm |
| | -Wet | 2 | Non Sticky Non Plastic | Slightly Sticky Slightly Plastic | Sticky, Plastic | v. sticky v. plasticSticky |
| 3.Topograhy( t) | Slope % | 2 | 2-4 | 4.8 | 8-16 | 30-50 |
| Porosity/Abund/cm2 | | 2 | 200 | 100-200 | 50-100 | <50 |
| 4. Wetness | | 6 | | | | |
| | Drainage Class | 3 | MWD | PD | Por aeric | VPD |
| | Groundwater table, cm | 3 | <50 | 50-100 | 100-200 | >200 |
| 5. Climate | | 5 | | | | |
| | Annual Rainfall (mm) | 2 | 1250-1600 | 1600-1800 | >1800 | 550-500 |
| 6. Soil Physical Characteristics | | 4 | | | | |
| | Texture Class | 3 | CS, SCL, | SL, LFS, LS, | LCS FS | CM, CL |
| | Soil Depth(cm) | 3 | 75-100 | 50-75 | 30-50 | 20-30 |
| | Ideal Index of soil condition maize production | | | | | |
| | >80 | 40-80 | 20-40 | >20 >80 | 40-80 20-40 | <20 |

**KEY**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| VPD | = Very Poorly Drained | PD | = Poorly Drained | MWD | = Moderately Well Drained | WD | = Well Drained |
| SCL | = Sandy Clay Loam | LS | = Loamy Sand | L | = Loam | SiL | = Silty Loam |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| SL | = Sandy Loam | SiCL | = Silty Clay Loam | CL | = Clay Loam | SiC | = Silty Clay |
| Si | = Silt | SC | = Sandy Clay | C | = Clay | S | = Sand |
| ESP | = Exchangeable Sodium Percentage | Cm | = massive clay; | Fs | = fine sand; | | |

**Table 3.6: Rating of Land Qualities Representing Soil Conditions for sugarcane Production;** Modified from Berhanu: (1980) and Sys (1985)

| Land Quality | Land Characteristics | Wt | High (S1) | Moderate (S2) | Low (S3) | Very Low (N1) |
|---|---|---|---|---|---|---|
| Land Quality Score | | 4 | 3 | 2 | 1 | 0 |
| 1. Fertility Status | Organic carbon % | 1 | 1.2.2 | 1.0-1.2 | 0.8-1.0 | 0.6-0.8 |
| | Total Nitrogen % | 1 | >25 | 6-25 | <6 | >2 |
| | Available P (Bray 2)m/kg | 1 | 0.153 | 0.76-0.153 | 0.076 | <0.076 |
| | Exch. K Cmol/kg | 1 | 6.1 | 7.9-8.4 | 4.0 | <4 |
| | pH | 1 | >0.8 | 4-0.80 | 1-0.4 | <0.1 |
| | CEC, cmol/kg | 2 | 16-24 | <16(-) | <16(+) | <10 |
| | Base Saturation% | 1 | 35-50 | 20-35 | 15-20 | <15 |
| 2. Workability | Soil Consistence | 6 | | | | |
| | -dry | 2 | Soft | Loose, Hard | Very hard | Extremely hard |
| | -Moist | 2 | Friable | Slightly hard, | Loose, Firm | very firm |
| | | | | | | Extremely firm |
| | -Wet | 2 | Non Sticky | Slightly Sticky | | v. sticky |
| | | | Non Plastic | Slightly Plastic | Sticky, Plastic | v. plasticSticky |
| 3.Topograhy( t) | Slope % | 2 | 2-4 | 4.8 | 8-16 | 30-50 |
| Porosity/Abund/cm2 | | 2 | 200 | 100-200 | 50-100 | <50 |
| 4. Wetness | | 6 | | | | |
| | Drainage Class | 3 | WD | MWD | PD | VPD |
| | Groundwater table, cm | 3 | <50 | 50-100 | 100-200 | >200 |
| 5. Climate | | 5 | | | | |
| | Annual Rainfall (mm) | 2 | 1600-2500 | 1200-1600 | 900-1200 | <900 |
| 6. Soil Physical Characteristics | | 4 | | | | |
| | Texture Class | 3 | CL, SCL, | SL, SLCC, SL, | SIC LS,CSS,CgsCacs | Si, CL, I |
| | Soil Depth(cm) | 3 | >100 | 50-100 | 25-50 | >25 |
| | Ideal Index of soil condition Sugar cane production | | | | | |
| | >70 | | 40-70 | 20-40 >20 >70 | 40-70 20-40 | <20 |

**KEY**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| VPD | = Very Poorly Drained | PD | = Poorly Drained | MWD | = Moderately Well Drained | WD | = Well Drained |
| SCL | = Sandy Clay Loam | LS | = Loamy Sand | L | = Loam | SiL | = Silty Loam |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| SL | = Sandy Loam | SiCL | = Silty Clay Loam | CL | = Clay Loam | SiC | = Silty Clay |
| Si | = Silt | SC | = Sandy Clay | C | = Clay | S | = Sand |
| ESP | = Exchangeable Sodium Percentage | Cm | = massive clay; | Fs | = fine sand | | |

## 3.5 Methodology

Table 3.3 was modified from rating of land qualities representing soil conditions, Berhanu (1980) and factor ratings of land use requirements for rice, Sys (1985). In Berhanu (1980), there were five land quality groups (nutrient status, workability, drainage, available water, and rooting depth) while Sys (1985) has climate, physical condition, wetness, fertility status and toxicity as land qualities. Due to the peculiar nature of coastal plain soils, the two tables were modified to produce Table 3.3. In this table, there are six land quality groups (fertility status, workability, toxicity, wetness, and climate and soil physical conditions). Each land quality group has specific land characteristics which were weighed in order of importance according to the crop requirements under study. The various suitability classes had land quality scores in a decreasing order of importance. The ideal index of soil condition for wetland or swamp rice production was established by multiplying the land quality scores of each land suitability class with the weights of the land groups which was eventually summed. The multiplication and addition of each land quality score with the weights of land characteristics gave the ideal index of soil condition for each suitability class. The land characteristics gave the ideal index of soil condition for each suitability class. The land characteristics from the various pedons falling under any suitability class range; such land quality score was multiplied by the weight which produced the land suitability, the summations of the suitability scores gave the obtained land quality index. This score determine the land suitability class of the mapping units. Kosuowei (2008) modified table 3.4 from Berhanu (1980) with the optimal requirements of cassava as a crop. The workings of table 3.4 are the same with that of Table 3.3, 3.5, and 3.6.

### 3.5.1 Land Suitability Classification for wetland or Swamp Rice

Land suitability classification for wetland or swamp rice in the study area was done using Table 3.3 The characteristics of the various pedons in the different mapping units in the study area (Table 3.3) was matched with ratings of land qualities representing soil condition for wetland or swamp rice production. (Table 3.3) The land suitability scores and obtained land quality index was calculated to determine the land suitability class (Table 4.9)

### 3.5.2 Land Suitability Evaluation for Cassava

Land suitability Evaluation for cassava in the study area was done using Table 3.4. The characteristics of the various pedons in the different mapping units in the study area (Table 3.4) was matched with ratings of land qualities representing soil condition for cassava production. (Table 3.4) The land suitability scores and obtained land quality index was calculated to determine the land suitability class (Table 4.9)according to Fu *et al.* (2004).

### 3.5.3 Land Suitability Classification for Maize

Land suitability classification for maize in the study area was done using Table 3.5. The characteristics of the various pedons in the different mapping units in the study area (Table 4.5) was matched with ratings of land qualities representing soil condition for maize production. (Table 3.5) The land suitability scores and obtained land quality index was calculated to determine the land suitability class (see Table 4.11) according to FU *et al*. (2004).

### 3.5.4 Land Suitability Classification for Sugarcane

Land suitability classification for sugarcane in the study area was done using Table 3.6. The characteristics of the various pedons in the different mapping units in the study area (Table 4.5) was matched with ratings of land qualities representing soil condition for sugarcane production. (Table3.6) The land suitability scores and obtained land quality index was calculated to determine the land suitability class (see Table 4.12) according to Fu*et al* (2004).

### 3.5.5 Data Analysis

Soil data were subjected to analysis of variance (ANOVA) using the Genstat Software. Means were separated using Least Standard of the Difference (LSD) at 5% level of probability. Coefficient of variability was used to determine the degree of variability of selected soil properties within the profile (Wilding *et al*, 1994).A correlation matrix of relationships between soil properties in the study area was used to show the relationship among soil properties.

# CHAPTER FOUR

## Results and Discussion

**4.1** Table 4.1shows the geographical coordinates of the profile pits in the study areas

**Table 4.1 Geographical Coordinates of Profile Pits in the Study Area**

| **Profile Name And Identity Code** | **Latitude** | **Longitude** | **Elevation (asl)** |
|---|---|---|---|
| Levee Crest (EO1) | 5º 46'086N | 6º 49' 345E | 121m |
| Levee Slope (EO2) | 5º42' 369N | 6º 49'012E | 116m |
| Terrace (EO3) | 5º 42'330N | 6º 48' 876E | 111m |
| Backswamp (EO4) | 5º 42'270N | 6o 48' 869E | 109m |

**Description of the Soil in the Geomorphic Units.**

### 4.1.1 Soils of the Well Drained Levee Crest

Pedon EO1 represents soils of the well-drained levee crests. Pedon of EO1 was located in Egwe at a settlement owned by Oguta. The pedon was located at latitude $5^{0}$46'086N and longitude $6^{0}$49'345E with elevation of 121m asl. The topography was nearly level, (1% slope). The area was well drained. It was a secondary bush interspersed with shrubs. It was used for cassava, intercropped with maize and few plantain stands.

The soils of the well-drained levee crest (pedon EO1) had brown colour (7.5YR 4/4; moist) at the surface horizons, whereas the color of the subsurface horizons varied from reddish grey (5YR 5/2; moist) to weak red (2.5YR 5/8; moist) and red (10R 4/8; moist). There were mottles found in the topsoil, (7.5YR3/5; moist). Color of the mottles found in the subsoil varied from common, coarse, distinct, and light reddish brown (5YR 4/3; moist) to common, medium, faint (2.5YR3/5; moist) reddish brown (10R 3/6; moist). The texture was sandy in the surface horizon, and sandy to loam in the subsurface horizon. The structure of the pedon levee crest (EO1) varied from weak, fine, very fine granular to moderate, in the surface horizon (topsoil).

The subsurface (subsoil) varied from, coarse to very coarse granular structure. The consistence of the top soil ranged from loose, friable, and non-sticky to non-plastic while that of subsoil varied from firm, non- sticky to non-plastic. There was abundant root medium, seen on the surface horizon with medium to few to abundant seen on the subsurface horizons. There were also termite activities found. The diagnostic surface horizon was Ochric epipedon, the diagnostic subsurface horizon was Kandic. The pedon had a depth of 0-200cm.

**4.1.2 Soils of the moderately Drained Levee Slopes**

Pedon EO2 represents the soils of the moderately drained levee slope. The pedon was located at latitude $5^{0}$42'369N and longitude $6^{0}$49'012E with elevation of 116m and a topography of nearly level, 1.5% slope. The soil was moderately well drained and the pedon was located in secondary bush with interspersed trees.

The colour of the surface horizon (top soil) varied from dark brown (7YR3/3) moist, to strong brown (7YR 5/8) moist, light reddish brown (5YR 6/3) moist to light red (2.5YR 6/6) moist to (2.5YR 7/8) moist in the subsurface horizon (sub soil) moist. The mottles in the surface horizons of the soil was many, dark brown (7.5YR4/5) moist. The mottles found in the subsurface horizon were many, common, medium distinct (5YR3/5, 2.5YR2/5, 2.5YR 4/5, 2.5YR 6/8) moist. The texture was sandy on the surface horizon and sandy loamy on the subsurface. The structure varied from structureless single grain on the surface (top soil) to weak fine, coarse, very coarse to medium coarse granular structure on the subsurface horizons (subsoil). The consistence of the surface horizon (top soil) was loose, non-sticky, non-plastic, while the subsurface horizons varied from friable, firm to firm sticky, non-sticky, and non-plastic. There was abundant root medium on the surface (top soil) with very few to abundant root medium on the subsurface (sub soil) horizons. Termites' activities were seen in the surface horizon (topsoil). Common to termite activities were seen in the subsurface horizon (subsoil). The diagnostic surface horizon was Ochric epidedon that of the subsurface horizon was Kandic. The pedon had a depth of 0 - 200cm.

### 4.1.3 Soils of the Poorly Drained Terraces

Pedon EO3 represented soil of the poorly drained terrace. The pedon was located in latitude $5^{0}$42'330N and longitude $6^{0}$48'876E with elevation of 111M.The topography of the pedon was 3% slope. The soil was poorly drained; the pedon was sited in secondary bush with interrupted trees.

The colour of the soil varied from very dark grey (7.5YR 3/1) moist on the surface horizon (subsoil) to yellowish red (5YR 5/6) moist, reddish yellow (5YR 6/6) moist, reddish brown (5YR 5/4) moist, to yellowish red (5YR 4/6) moist on the subsurface horizons (subsoil). The colour of the mottles in the surface horizon varied from common medium dark grey (7YR 4/3) moist. However, the subsurface horizons of the pedon varied from common, medium, distinct yellowish red (5YR 4/6), common, medium, distinct reddish yellow (5YR 5/7), to few, fine, faint yellowish red (5YR3/2) and (5YR 3/4). The texture was sandy on the surface horizon (topsoil) and, sandy loam, on the subsurface horizons (subsoil). The structure of the surface horizons for the pedon varied from weak, fine, granular structure on the surface (topsoil) to weak coarse, moderate coarse granular structure, moderate very coarse granular structure. The consistence of the surface horizons for the pedon varied from loose, non-sticky, non-plastic on the surface (topsoil) to very friable non-sticky, non-plastic, friable, firm on the subsurface horizons. There was an abundant root medium on the surface horizon with medium to few, and termite activity seen on the subsurface (subsoil). The diagnostic horizon was Ochric epidedon that of the subsurface horizon was Kandic. The pedon had a depth of 0 - 200cm

### 4.1.4 Soils of the very poorly Drained Backswamps

Pedon EO4 represented soils of the very poorly drained backswamp. The pedon was located in latitude $5^0$42'270N and longitude $6^0$48'869E with elevation of 109m.The topography of the pedon was 4% slope. The soil was very poorly drained, and the pedon was sited in a swamp forest. The colour of the surface horizon of the pedon varied from yellowish red (5YR4/6) moist on the surface (topsoil) to yellowish red 5YR 5/8) moist, and weak red (2.5YR 5/12) moist on the subsurface horizons (subsoil). The colour of the mottles in the surface horizon (topsoil) varied from common, medium prominent yellowish red (5YR 6/8) moist. However, the colour of the mottles on the subsurface horizon varied from few distinct yellowish red (5YR2/4) moist to common medium, distinct weak red (2.5YR 4/3) moist. The texture of the pedon is sandy on the surface horizon while that of the subsurface horizon vary sandy to sandy. The structure of the pedon was weak coarse granular structure on the surface horizon (topsoil) while the subsurface (subsoil) varied from weak coarse granular structure to very coarse granular structure. The consistence of the pedon was loose, non-sticky, non-plastic on the surface horizon (topsoil) while the subsurface horizon varied from friable to very friable non-sticky and non-plastic. There was abundant root medium on the surface horizon (topsoil) with few to medium roots in the subsurface horizon (subsoil) many termite activitieswere seen on the  surface soil horizon (topsoil) while few was found on the subsurface horizon (subsoil). The diagnostic surface horizon was Ochric epidedon, the diagnostic subsurface horizon was Kandic. The pedon had depth of 0 -100cm

## 4.2 Morphological Properties

Data on the morphological properties of the soils are presented in Table 4.2

**Table 4.2: Macro- Morphological Features of the Soils in the Study Area**

| Horizon | Depth (cm) | Color (Moist) | Mottles | Texture | Structure | Consistence Dry | Consistence Moist | Consistence Wet | Rootlet | Boundary | Faunal Activities |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | **Levee Crest Soil EO1** | | | | | | |
| A | 0-10 | 7.5YR4/4 | 7.5YR3/5cm2p | S | 1cgr | 1 | ml | ns, np | Abundant | ds | Termite Activities |
| AB | 10-35 | 5YR5/2 | 5YR4/3c2d | S | 1cgr | 3 | mfi | ns, np | Abundant | ds | Medium |
| $Bg_1$ | 35-120 | 2.5YR5/8 | 2.5YR3/5fd | s | 1vcgr | s | mfr | ns, np | Vfew | ds | Few |
| $Bg_2$ | 120-200 | 10R4/8 | 10R3/6cm2p | s | 1vcgr | 2 | mfi | ns, np | Abundant | | Termite Activities |
| | | | | | **EO2 Levee Slope** | | | | | | |
| A | 0-21 | 7.5YR3/3 | 7.5YR4/5cm2p | S | 1cgr | 1 | ml | ns, np | Abundant | cs | Termite Activities |
| AB | 21-35 | 7YR5/8 | 7YR3/5c2d | S | 1fgr | s | mfr | ns, np | Abundant | cs | Medium |
| $Bg_1$ | 35-65 | 5YR6/3 | 5YR2/4f1f | Ls | 2cgr | 1 | mfi | ns, np | V.few | cs | Few |
| $Bg_2$ | 65-108 | 2.5YR6/6 | 2.5YR4/5f1f | Ls | 2vcgr | 2 | mfi | ns, np | Abundant | Cs | Few |
| $Bg_3$ | 108-200 | 2.5YR7/8 | 2.5YR6/8cm2p | L s | 2cgr | 2 | mfi | ns, np | Abundant | | Few |

## Macro-morphological Features of the Soils in the Study Area

| Horizon | Depth (cm) | Color (Moist) | Mottles | Texture | Structure | Consistence Dry | Consistence Moist | Consistence Wet | Rootlet | Boundary | Faunal Activities |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | **EO3 Terrace** | | | | | | |
| A | 0-5 | 7.5YR3/1 | 7.5YR4/3cm2 | S | 1cgr | 1 | ml | ns, np | Abundant | cs | Termite Activities |
| AB | 5-34 | 5YR5/6 | 5YR4/6c2d | S | 1cgr | s | mvfr | ns, np | Medium | cs | Medium |
| BA | 34-56 | 5YR6/8 | 5YR5/76c2d | LS | 2cgr | 1 | mfr | ns, np | Medium | cs | Medium |
| $Bg_1$ | 56-98 | 5YR5/4 | 5YR3/2f1f | LS | 2vcgr | 1 | mfi | ns, np | Few | cs | Few |
| $Bg_2$ | 98-200 | 5YR7/8 | 5YR3/4f1f | L S | 2vcgr | 1 | mfi | ns, np | Vfew | cs | Few |
| | | | | | **Back Swamp Soil** | | | | | | |
| A | 0-4 | 5YR4/6 | 5YR6/8cm2p | S | 1fgr | 1 | ml | ns, np | Abundant | cs | Termite Activities |
| B | 4-84 | 5YR5/8 | 5YR2/4fd | S | 1cgr | s | mfi | ns, np | Medium | dw | Medium |
| C | 84-100 | 2.5YR5/2 | 2.5YR4/3c2d | S | 1cgr | 1 | mfi | ns, np | Vfew | dw | Few |

**Legend for Table 4.2**(Note that all symbols used here conform with soil survey manual USDA Handbook NO. 18 pp 139-140 1951)

**Mottling**

| Abundance | Size | Contrast |
|---|---|---|
| Few.............................f | Fine.................................1 | Faint..............................f |
| Common....................c | Medium...........................2 | Distinct.........................d |
| Many..........................m | Coarse.............................3 | Prominent.....................p |

**Texture**

| | |
|---|---|
| | Sandy...........................s |
| sandy loam................SL | |
| Clay Loam......................CL | |
| Loamy sand................LS | Silt Clay Loam..............SICL |
| Sandy Clay loam.......SCL | Silt Clay........................SiC |
| Loam............................L | Clay................................C |
| Clay Loam..................CL | Sandy Clay.....................SC |

**Structure**

| **Size:** | **Grade** | **Type** |
|---|---|---|
| Very fine....................vf | Stuctureless....................O | Angular blocky.........abk |
| Fine............................f | Weak..............................1 | Subangular Blocky...sbk |
| Medium....................m | Moderate........................2 | Granular....................gr |
| Coarse.......................c | Strong.............................3 | Single grain..............sg |
| | | Massive......................m |

**Consistence**

| **Moist Soil** | **Wet Soil** | **Dry Soil** |
|---|---|---|
| Loose...................ml | Non Sticky.....................ns | Soft.............................s |
| very friable........mvfr | Non Plastic....................np | Loose...........................1 |
| Friable................mfr | Slightly Sticky................ss | Hard............................h |
| Firm.....................mfi | Sticky..............................s | Very hard...................vh |
| Very Firm...........mvfi | Slightly Plastic................sp | Extremely hard..........eh |
| Extremely Firm..mefi | Very Sticky.....................vs | |

**Boundary**

Distinctness

Angular- a: clear-c: granular- g: diffuse- d Topography: Smooth- s: wavy- w: Irregular- I: Broken- b

## Physical Properties

### 4.2.1 Particle Size Distribution

The values of g/kg sand in the soils of the study area Pedon levee crest- backswamp (EO1-EO4) and surface soil samples (EO1S-EO4S) ranged from 836.0-956.0g/kg with mean values of 921.0g/kgfor pedon levee crest(EO1), 880.0g/kg for pedon levee slope(EO2),931.8g/kg for pedon terrace(EO3),883.0g/kg for pedon backswamp(EO4), 871.0g/kg for surface soil sample EO1S, 896.0g/kg for surface soil samples of EO2S, 911.0g/kg for surface soil samples of EO3S and 861g/kg for surface soil sample of EO4S.

The values of the g/kg silt in the study area ranged from 00.0g/kg-16.0g/kg with mean values of 16.0g/kg for both the Pedons and surface soil samples.The values of g/kg clay in the soils ranged from 280.0g/kg-148.0g/kg with meanvaluesof 630.g/kg in pedon levee crest (EO1), 102.8g/kg in pedon levee slope (EO2), 520.0g/kg in pedon terrace(EO3), 940.0g/kg in pedon backswamp (EO4) and surface soil samples of 452.0g/kg for EO1S, 880.0g/kg for EO2S, 292.0g/kgfor EO3S and 123.0g/kg for EO4S.

### 4.2.2 Bulk Density

The values of bulk density obtained from the soils of the study area (pedons) leveecrest - backswamp (EO1-EO4) ranged from 0.94mg/m$^3$-1.34mg/m$^3$with mean value of 1.23mg/m$^3$levee crest (EO1), 1.19mg/m$^3$leveeslope(EO2),1.16mg/m$^3$terrace(EO3)and 1.22mg/m$^3$backswamp(EO4). While the surface soil samples ranged from 0.62mg/m$^3$ -1.25mg/m$^3$with mean values of 1.09mg/m$^3$ in EO1S, 0.99mg/m$^3$EO2S, 0.94mg/m$^3$EO3S and 1.09mg/m$^3$ EO4S.

### 4.2.3 Total Porosity

The values of total porosity in the soils (pedons EO1-EO4) ranged from 49.43%- 69.06% with mean values of 53.78%, 55.02%, 56.15%, and 53.96% EO1, EO2, EO3, and EO4 respectively.However,the surface soil samples ranged from 23.22%-47.83% with mean values of 41.68% in EO1S, 40.21% EO2S, 35.72% EO3S, and 41.68% EO4S.

### 4.2.4 Moisture Content

The percentage moisture content obtained from the soils of the studied area pedons (EO1-EO4) ranged from 7.20% -28.4% with mean values of 8.31% EO1, 9.23% EO2, 9.86% EO3 and 24.65% EO4 while the surface samples ranged from 6.97% -28.78% with mean values of 8.20% EO1S, 8.02% EO2S, 9.52% EO3S, and 23.83% EO4S.

The data on physical properties are presentedin Table 4.3

## Table 4.3: Physical Characteristic of Soils of the Study Area (Pedon)

| Horizon Designation | Depth (cm) | Bulk Density (mg/m$^3$) | Moisture content (%) | Total Porosity (%) | Particle Size Distribution (g/kg) Sand 2-0.05mm | Silt 0.05-002mm | clay <0.002mm | Textural Class |
|---|---|---|---|---|---|---|---|---|
| | | | **Levee Crest Soils (Typic Eutrudepts)** | | | | | |
| A | 0-20 | 1.12 | 8.56 | 57.74 | 896.0 | 16.0 | 88.0 | sandy loam |
| AB | 20-65 | 1.24 | 8.92 | 53.21 | 916.0 | 16.0 | 68.0 | sandy loam |
| $Bg_1$ | 65-120 | 1.27 | 8.01 | 52.08 | 936.0 | 16.0 | 48.0 | sandy loam |
| $Bg_2$ | 120-200 | 1.27 | 7.79 | 52.08 | 936.0 | 16.0 | 48.0 | sandy loam |
| | **Mean** | **1.23** | **8.32** | **53.78** | **922.1** | **16.0** | **63.0** | |
| | | | **Levee Slope Soils (Typic Hapludult)** | | | | | |
| A | 0-21 | 0.94 | 7.20 | 64.53 | 896.0 | 16.0 | 88.0 | sandy loam |
| AB | 21-35 | 1.16 | 8.91 | 56.23 | 896.0 | 16.0 | 68.0 | sandy loam |
| $Bg_1$ | 35-65 | 1.25 | 9.20 | 52.83 | 856.0 | 16.0 | 48.0 | loamy sand |
| $Bg_2$ | 65-108 | 1.29 | 9.56 | 51.32 | 876.0 | 16.0 | 48.0 | loamy sand |
| $Bg_3$ | 108-200 | 1.32 | 10.76 | 50.19 | 876.0 | 16.0 | 48.0 | loamy sand |
| | **Mean** | **1.19** | **9.23** | **55.02** | **880.0** | **16.0** | **60.0** | |
| | | | **Terrace (Typic Hapludult)** | | | | | |
| A | 0-5 | 0.82 | 8.05 | 69.06 | 896.0 | 16.0 | 88.0 | sandy loam |
| AB | 5-34 | 1.22 | 8.55 | 53.96 | 856.0 | 16.0 | 88.0 | sandy loam |
| $B_A$ | 34-56 | 1.23 | 11.43 | 53.58 | 956.0 | 16.0 | 28.0 | sandy loam |
| $Bg_1$ | 56-98 | 1.24 | 10.98 | 53.21 | 956.0 | 16.0 | 28.0 | sandy loam |
| $Bg_2$ | 98-200 | 1.30 | 10.30 | 50.24 | 956.0 | 16.0 | 28.0 | sandy loam |
| | **Mean** | **1.16** | **9.86** | **56.15** | **931.8** | **16.0** | **52.0** | |
| | | | **Backswamp Soils (Typic Endoaquepts)** | | | | | |
| A | 0-4 | 1.00 | 21.91 | 62.26 | 876.0 | 16.0 | 88.0 | loamy sand |
| B | 4-84 | 1.32 | 23.20 | 50.19 | 896.0 | 16.0 | 68.0 | sandy loam |
| C | 84-100 | 1.34 | 28.84 | 49.43 | 896.0 | 16.0 | 48.0 | sandy loam |
| | **Mean** | **1.22** | **24.65** | **53.96** | **889.3** | **16.0** | **63.0** | |

**Physical Characteristic of theSurface Soils Samples of the Study Area**

| Replicates | Depth (cm) | Bulk Density ($mg/m^3$) | Moisture content (%) | Total Porosity (%) | Particle Size Distribution (g/kg) Sand 2-0.05mm | Silt 0.05-002mm | clay <0.002mm | Textural Class |
|---|---|---|---|---|---|---|---|---|
| | | | | **Levee Crest Surface Soils (Typic Eutrudepts)** | | | | |
| | 0-20 | 1.08 | 8.1 | 41.19 | 856.0 | 16.0 | 128.0 | sandy loam |
| | 0-20 | 1.07 | 8.25 | 40.80 | 876.0 | 16.0 | 108.0 | Sandy loam |
| | 0-20 | 1.10 | 7.89 | 41.97 | 856.0 | 16.0 | 128.0 | Sandy loam |
| | 0-20 | 1.12 | 8.56 | 42.75 | 896.0 | 16.0 | 88.0 | Sandy loam |
| | **Mean** | **1.09** | **8.20** | **41.68** | **871.0** | **16.0** | **113.0** | |
| | | | | **Levee Slope Soils (Typic Hapludults)** | | | | |
| | 0-20 | 0.74 | 6.97 | 27.91 | 896.0 | 16.0 | 88.0 | sandy loam |
| | 0-20 | 1.12 | 8.90 | 42.75 | 896.0 | 16.0 | 88.0 | Sandy loam |
| | 0-20 | 1.16 | 8.99 | 44.31 | 896.0 | 16.0 | 88.0 | Sandy loam |
| | 0-20 | 0.94 | 7.20 | 45.88 | 896.0 | 16.0 | 88.0 | Sandy loam |
| | **Mean** | **0.99** | **8.02** | **40.21** | **896.0** | **16.0** | **88.0** | |
| | | | | **Terrace Soils (Typic Hapludults)** | | | | |
| | 0-20 | 0.62 | 8.00 | 23.22 | 936.0 | 16.0 | 48.0 | sandy loam |
| | 0-20 | 1.14 | 8.20 | 43.53 | 916.0 | 16.0 | 68.0 | Sandy loam |
| | 0-20 | 1.18 | 11.11 | 45.09 | 896.0 | 16.0 | 88.0 | Sandy loam |
| | 0-20 | 0.82 | 10.78 | 31.03 | 896.0 | 16.0 | 88.0 | Sandy loam |
| | **Mean** | **0.94** | **9.52** | **35.72** | **911.0** | **16.0** | **73.0** | |
| | | | | **Backswamp Soils (Typic Endoaquepts)** | | | | |
| | 0-20 | 0.90 | 21.84 | 34.16 | 876.0 | 16.0 | 108.0 | loamy sand |
| | 0-20 | 1.25 | 22.80 | 47.83 | 836.0 | 16.0 | 148.0 | loamy Sand |
| | 0-20 | 1.22 | 28.78 | 46.66 | 876.0 | 16.0 | 128.0 | loamy Sand |
| | 0-20 | 1.00 | 21.91 | 38.06 | 866.0 | 16.0 | 108.0 | loamy Sand |
| | **Mean** | **1.09** | **23.83** | **41.68** | **86.1** | **1.6** | **123.0** | |

## 4.3 Chemical Characteristics

### 4.3.1 Soil Reaction (pH)

The pH ($H_20$) of the soil samples ranged from 5.99 - 6.84 levee - backswamp (pedons EO1 - EO4) with mean values of 6.31 levee crest (EO1), 6.00 levee slope (EO2), 6.36 terrace (EO3), and 6.54 backswamp (EO4). The pH values of surface samples ranged from 5.65 - 6.49 with mean values of 6.21 (EO1S), 5.97 (EO2S), 5.85 (EO3S), 6.21 (EO4S) [in 1NKCl], indicating the existence of the soils as slightly acidic in nature. The mean average values of 0 - 40cm soils for all the pedons (EO1-EO4) were 6.15 (EO1), 6.08 (EO2), 6.16 (EO3), 6.64 (EO4), while the 40 - 200cm are 6.46 (EO1), 5.88 (EO2), 6.39 (EO3), 6.54 (EO4).

### 4.3.2 Total Nitrogen (T.N)

The values of total nitrogen in the soils of the study area ranged from 0.014% - 0.120% in Levee - backswamp pedons (EO1 - EO4) with mean 0.022% levee crest (EO1), 0.055% levee slope (EO2), 0.031% terrace (EO3) and 0.039% in backswamp (EO4). However the percentage total nitrogen observed in the surface soils of the studied area ranged from 0.035% - 0.114% (EO1S - EO4S) with mean values of 0.066% levee crest surface sample (EO1S), 0.075% levee slope surface samples (EO2S), 0.073% terrace surface samples (EO3S), and 0.068% in backswamp surface samples (EO4S) respectively, The mean average values of 0 - 40cm soils for all the pedons (EO1 - EO4) were 0.026% (EO1), 0.059% (EO2), 0.050% (EO3), 0.004% (EO4) while the 40 - 200cm were 0.016% (EO1), 0.052% (EO2), 0.019% (EO3), 0.039% (EO4).

### 4.3.3 Organic Carbon

The values of organic carbon in all the soils studied ranged from 0.22% to 0.83%Levee – backswamp pedons (EO1-EO4)with mean values of 0.34% levee crest(EO1), 0.27% levee slope (EO2), 0.38%terrace,(EO3), and 0.55% backswamp(EO4) while the values of surface samples ranged from 0.50%-1.40 (EO1S-EO4S) with mean values of 0.64% (EO1S), 0.69% (EO2S), 0.68% (EO3S) and 0.82%( EO4S). The mean average values of 0-40cm soils for all the pedons (EO1-EO4) were 0.44% (EO1), 0.53% (EO2), 0.57% (EO3), 0.60% (EO4), while those of 40-200cm were 0.46%(EO1), 0.09% (EO2), 0.26% (EO3), and 0.46% (EO4).

### 4.3.4 CN Ratio

The values of carbon : nitrogen in all the soils studied ranged from 0.83%-19.00 levee crest - backswamp pedons (EO1 - EO4) with mean values of 15.53% levee crest, (EO1) 5.78% levee slope, 13.58% terrace and 14.05% backswamp while the surface soil sample ranged from 0.10% - 17.03% (EO1S - EO4S) with mean values of 8.10% (EO1S), 7.01% (EO2S) 9.58% (EO3S), 12.58% (EO4S).

The mean average values of 0 - 40cm for all the soil pedons were 16.65% levee crest (EO1), 9.70% levee slope (EO2), 12.79% terrace (EO3), 15.20% backswamp (EO4) While the 40 - 200cm depth were 14.42% levee crest (EO1), 3.16% levee slope (EO2), 14.15% terrace (EO3) backswamp (EO4) 0.92%.

### 4.3.5 Exchangeable Basic Cations (Calcium)

The values of exchangeable calcium in all the soils studied ranged from 1.10cmol/kg - 2.16cmol/kg, levee - backswamp pedons ( EO1 - EO4) with mean values of 1.69cmol/kg levee crest (EO1), 1.88cmol/kg levee slope (EO2), 1.74cmol/kg terrace (EO3), 1.76%cmol/kg backswamp (EO4). However, the values of exchangeable calcium in surface soil samples ranged from

1.52cmol/kg - 3.26cmol/kg (EO1S - EO4S) with mean values of 2.29cmol/kg (EO1S), 2.21cmol/kg (EO2s), 2.21cmol/kg (EO3S), 1.71cmol/kg (EO4S). The mean average values of 0 - 40cm for all the soil pedons were 1.63cmol/kg (EO1), 1.78 cmol/kg (EO2), 1.99cmol/kg (EO3), 2.04cmol/kg (EO4), while the 40cm - 200cm depth were 1.56cmol/kg (EO1), 1.95cmol/kg (EO2), 1.57cmol/kg (EO3), and 1.20cmol/kg (EO4).

## Exchangeable Magnesium

The values of exchangeable magnesium in all the soils studied ranged from 1.00cmol/kg - 2.50cmol/kg levee - backswamp (EO1-EO4), with mean values of 1.70cmol/kg levee crest (EO1), 1.42cmol/kg levee slope (EO2), 2.20cmol/kg terrace, 1.60cmol/kg backswamp (EO4), while the surface soils ranged from 0.10cmol/kg - 2.20cmol/kg (EO1S-EO4S) with mean values of 1.28cmol/kg (EO1S), 1.20cmol/kg (EO2S), 1.23cmol/kg (EO3S), 1.73cmol/kg (EO4S). The mean average values of 0 - 40cm for all the soil pedons were 1.40cmol/kg levee crest (EO1), 1.90cmol/kg levee slope (EO2), 1.75cmol/kg terrace (EO3), 1.75cmol/kg backswamp (EO4). While the 40cm - 200cm depth were 2.00cmol/kg (EO1), 1.10cmol/kg (EO2), 2.50cmol/kg (EO3), 1.30cmol/kg (EO4).

## Exchangeable Potassium

The values of exchangeable potassium in all the soils of the geomorphic units studied ranged from 0.08cmol/kg - 2.13cmol/kg levee - backswamp pedons (EO1-EO4), with mean values of 0.50cmol/kg levee crest (EO1), 0.90cmol/kg, 0.68cmol/kg, 0.78cmol/kg while that of the surface soil samples ranged from 0.29cmol/kg - 1.48cmol/kg with mean values of 0.67cmol/kg, 0.89cmol/kg, 0.82cmol/kg, 0.77cmol/kg. The mean average values of 0-40cm for all the soil pedons were 0.89cmol/kg, 1.15cmol/kg, 0.66cmol/kg, and 0.82cmol/kg. While those of 40cm-200cm depth were 0.11cmol/kg, 1.26cmol/kg, 0.69cmol/kg, and 0.79cmol/kg.

## Exchangeable Sodium

The values of exchangeable sodium in all the soils studied ranged from 0.01cmol/kg - 0.09cmol/kg levee – backswamp pedons (EO1-EO4) with mean values of 0.11cmol/kg levee crest EO1), 0.07cmol/kg levee slope (EO2), 0.08cmol/kg terrace (EO3), 0.08cmol/kg backswamp (EO4), while the surface soil samples ranged from 0.07cmol/kg - 0.12cmol/kg (EO1S -EO4S) with mean values of 0.11cmol/kg (EO1S), 0.11cmol/kg (EO2S), 0.09cmol/kg (EO3S), 0.09cmol/kg (EO4S). The mean average values of 0 - 40cm for all the soil pedons were 0.11cmol/kg (EO1), 0.10cmol/kg (EO2), 0.08cmol/kg (EO3), 0.09cmol/kg (EO4). While the 40cm - 200cm depth were 0.06cmol/kg (EO1), 0.10cmol/kg (EO2), 0.08cmol/kg (EO3), 0.08cmol/kg (EO4).

### 4.3.6 Exchangeable Acidity (H + Al)

The values of exchangeable acidity (Hydrogen + Aluminum) in all the soils studied ranged from 0.06cmol/kg - 1.28 cmol/kg levee – backswamp pedons (EO1-EO4) with mean values of 0.75cmol/kg (EO1), 0.98cmol/kg (EO2), 0.65cmol/kg (EO3), 0.12 cmol/kg (EO4). While the surface soil samples ranged from 0.06cmol/kg - 1.16cmol/kg (EO1S-EO4S) with mean values of 0.85cmol/kg (EO1S), 1.55cmol/kg (EO2S), 0.57cmol/kg (EO3S), 0.47cmol/kg (EO4S). The mean average values of 0 - 40cm for all the soil pedons were 0.98cmol/kg (EO1), 0.88cmol/kg (EO2), 0.70cmol/kg (EO3), 0.10cmol/kg (EO4). While the 40cm - 200cm depth were 0.50cmol/kg (EO1), 1.05cmol/kg (EO2), 0.63cmol/kg (EO3), 0.16cmol/kg (EO4).

## Exchangeable Aluminum

The values of exchangeable Aluminum in all the soils studied ranged from 0.02cmol/kg - 0.27cmol/kg levee - backswamp pedons (EO1 -

EO4) with mean values of 0.19cmol/kg (EO1), 0.25cmol/kg (EO2), 0.16cmol/kg (EO3), 0.03cmol/kg (EO4). However, the surface soil sample ranged from 0.02cmol/kg -0.31cmol/kg (EO1S - EO4S) with mean values of 0.20 (EO1S), 0.28 (EO2S), 0.21 (EO3S) (EO4S), 0.12. The mean average values of 0-40cm for all the soil pedons were 0.25cmol/kg(EO1), 0.22cmol/kg (EO2), 0.18cmol/kg(EO3), 0.03cmol/kg (EO4). While those of 40cm-200cm depth were 0.26cmol/kg (EO1), 0.26cmol/kg (EO2), 0.16cmol/kg (EO3), 0.04cmol/kg (EO4).

## Exchangeable Hydrogen

The values of exchangeable hydrogen in all the soils ranged from 0.06cmol/kg - 0.81cmol/kg, levee - backswamp pedons (EO1 - EO4) with mean values of 0.56cmol/kg (EO1), 0.74cmol/kg (EO2), 0.49cmol/kg (EO3), 0.09cmol/kg (EO4), while the surface soil samples ranged from 0.06cmol/kg - 0.94cmol/kg, (EO1S - EO4S) with mean values of 0.66cmol/kg (EO1S), 0.83cmol/kg (EO2S), 0.62cmol/kg (EO3S), 0.35cmol/kg (EO4S).The mean average values of 0-40cm for all the soil pedons were 0.74cmol/kg (EO1), 0.66cmol/kg (EO2), 0.53cmol/kg (EO3), 0.08cmol/kg (EO4). While the 40cm - 200cm depth were 0.39cmol/kg (EO1), 0.79cmol/kg (EO2), 0.47cmol/kg (EO3), 0.12cmol/kg (EO4).

### 4.3.7 Total Exchangeable Base (TEB)

The values of total exchangeable base in all the soils studied ranged from 2.55% - 4.44% levee - backswamp pedons (EO1-EO4) with mean values 3.58% (EO1), 3.51% (EO2), 4.20% (EO3), 3.51% (EO4) while the surface soil sample ranged from 2.41% - 5.51% (EO1S - EO4S) with mean values of 3.84% (EO1S), 3.85% (EO2S), 3.66% EO3S), 3.67% (EO4S). The mean average values of 0 - 40cm for all the soil pedons were 3.20% (EO1), 3.94% (EO2), 4.16% (EO3), and 3.95% (EO4). While the 40cm - 200cm depth were 3.97% (EO1), 3.23% (EO2), 4.23% (EO3), and 2.63% (EO4).

### 4.3.8 Effective Cation Exchange Capacity

The values of total effective cation exchange capacity in all the soils ranged from 2.79cmol/kg - 5.28cmol, levee - backswamp pedons (EO1 - EO4) with mean values of 4.20cmol/kg (EO1), 4.50cmol/kg (EO2), 2.91cmol/kg (EO3), and 3.63cmol/kg (EO4). While the surface soil sample ranged from 3.21cmol/kg -5.38cmol/kg (EO1S-EO4S), with mean values of 4.69cmol/kg (EO1S), 4.40cmol/kg

(EO2S), 4.23cmol/kg (EO3S), 4.14cmol/kg (EO4S). The mean average values of 0-40cm for all the soil pedons were 4.18cmol/kg (EO1), 4.82cmol/kg (EO2), 4.61cmol/kg (EO3), 4.05cmol/kg (EO4). While the 40cm -200cm depth were 4.22cmol/kg (EO1), 3.94cmol/kg (EO2), 4.86cmol/kg (EO3), 2.79cmol/kg (EO4).

### 4.3.9 Percentage Base Saturation (%BS)

The values of total cation exchange capacity in all the studied soils ranged from 70.25% - 98.64% levee - backswamp pedons (EO1 - EO4) with mean values of 84.84% (EO1), 77.97% (EO2) , 85.23% (EO3), 96.45% (EO4), while the surface soil sample ranged from 75.08% - 129.03% (EO1S - EO4S), with mean values of 81.57% (EO1S), 99.61% (EO2S), 86.06% (EO3S), 89.22% (EO4S). The mean average values of 0 - 40cm for all the soil pedons were 75.81% (EO1), 81.83% (EO2), 91.28% (EO3), and 97.55% (EO4). While the 40cm - 200cm depth were 95.88% (EO1), 75.40% (EO2), 81.19% (EO3), and 94.22% (EO4).

### 4.3.10 Exchangeable Sodium Percentage (ESP)

The values of exchangeable sodium percentage in the soils of the study area ranged from 1.04% - 2.86% levee - backswamp pedons

(EO1-EO4) with mean values of 2.11% (EO1), 2.13% (EO2), 1.74% (EO3), and 2.19% (EO4). However, that of surface soil sample ranged from 1.52% - 3.12%, (EO1S - EO4S) with mean values of 2.28% (EO1S), 2.53% (EO2S), 2.29% (EO3S) 2.18% (EO4S). The mean average values of 0 - 40cm for all the soil pedons were 1.76% (EO1), 2.16% (EO2), 1.78% (EO3), and 1.86% (EO4). While those of 40cm - 200cm depth were 2.47% (EO1), 2.10% (EO2), 1.71%, (EO3) 2.86%. (EO4)

### 4.3.11 Aluminum Saturation

The values of aluminum saturation (Al sat.) in the soils of the study area ranged from 0.51% - 7.44% levee - backswamp pedons (EO1 - EO4) with mean values of 4.54% (EO1), 5.55% (EO2), 3.44% (EO3), 0.88% (EO4), While that of surface soil sample ranged from 0.57% - 22.18% (EO1S - EO4S) with mean values of 6.05% (EO1S), 4.65% (EO2S), 3.77% (EO3S), 0.61% (EO4S). The mean average values of 0 - 40cm for all the soil pedons were 3.03% (EO1), 6.15% (EO2), 4.05% (EO3), and 1.86% (EO4). However, the 40cm -200cm depth were 2.47%(EO1) 2.10% (EO2), 1.71% (EO3), 1.43% (EO4).

#### 4.3.12 Available Phosphorus

The values of available phosphorus (Avail. P) in the soils of the study area ranged from 0.10m/kg - 2.13m/kg levee - backswamp pedons (EO1 - EO4) with mean values of 0.50m/kg (EO1), 0.90m/kg (EO2), and 0.68m/kg (EO3),0.78m/kg (EO4). While the surface soil sample ranged from 0.29m/kg-1.48m/kg (EO1S - EO4S) with mean values of 0.67m/kg (EO1S), 0.89m/kg (EO2S) 0.82m/kg (EO3S), 0.77/m/kg (EO4S). The mean average values of 0 -40cm for all the soil pedon were 0.89m/kg (EO1), 1.15m (EO2), 0.66m/kg (EO3) 0.82m/kg (EO4). While those of 40cm - 200cm depth were 0.11m/kg (EO1), 1.26m/kg (EO2), 0.69m/kg (EO3), and 0.71m/kg (EO4).

#### 4.3.13 Calcium-Magnesium Ratio

The values of Calcium: Magnesium in all the soils ranged from 0.23% - 1.92% (EO1 - EO4) with mean values of 0.96% (EO1), 1.44% (EO2), 0.86% (EO3), 0.88% (EO4). However, the surface soil sample ranged from 0.28% -21.1% (EO1S - EO4S) with mean values of 1.34%1 (EO1S), 31% (EO2S), 6.44% (EO3S), 1.00% (EO4S). The mean average values of 0 - 40cm for all the soil pedon were 1.15% (EO1), 0.94% (EO2), 1.21% (EO3), and 1.20% (EO4). While those of

40cm - 200cm depth were 0.78% (EO1), 1.39% (EO2), 1.88% (EO3)and 0.23% EO4. Data on the chemical properties of the soils are contained in Tables 4.4

**Table 4.4: Chemical Characteristics of the Profile Samples in the Study Area**

| | | ← % → | | | | | | | ← Exchangeable Cations Cmol/Kg → | | | | | | | | | ← % → | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Horizon | Depth in Cm | s in $pH_2O$ | Soil pH in KCL | Tot N % | Org Carbon | C/NRati | Ca/Mg | Avail P µg/g | $Ca^{2+}$ | $Mg^{2+}$ | K | $Na^{2+}$ | Exch. $Al^{+}$cmo l/kg | Exch. $H^{+}$ | TEA | ECEC | TEB | Bs % | Esp | Al |
| **Levee Crest Soils (Typic Eutrudepts)** | | | | | | | | | | | | | | | | | | | | |
| A | 0-20 | 5.99 | 4.03 | 0.035 | 0.50 | 14.29 | 1.44 | 1.38 | 2.16 | 1.50 | 0.06 | 0.12 | 0.22 | 0.66 | 0.88 | 4.72 | 3.84 | 81.36 | 2.48 | 4.66 |
| AB | 20-40 | 6.31 | 14.14 | 0.020 | 0.38 | 19.00 | 0.85 | 0.40 | 1.10 | 1.30 | 0.06 | 0.09 | 0.27 | 0.81 | 1.08 | 3.63 | 2.55 | 70.25 | 1.04 | 7.44 |
| $Bg_1$ | 40-120 | 6.40 | 4.27 | 0.017 | 0.24 | 13.12 | 0.72 | 0.11 | 1.44 | 2.00 | 0.06 | 0.01 | 0.11 | 0.33 | 0.44 | 4.04 | 3.60 | 89.11 | 2.48 | 2.72 |
| $Bg_2$ | 120-200 | 6.52 | 4.37 | 0.014 | 0.22 | 15.71 | 0.84 | 0.10 | 1.68 | 2.00 | 0.01 | 0.11 | 0.15 | 0.45 | 0.06 | 4.40 | 4.34 | 98.64 | 2.45 | 3.34 |
| **Mean** | | **6.31** | **4.20** | **0.022** | **0.34** | **15.53** | **0.96** | **0.50** | **1.60** | **1.70** | **0.05** | **0.11** | **0.19** | **0.56** | **0.75** | **4.20** | **3.58** | **84.84** | **2.11** | **4.54** |
| **Levee Slope Soils (Typic Dystrudepts)** | | | | | | | | | | | | | | | | | | | | |
| A | 0-21 | 6.11 | 3.85 | 0.092 | 1.83 | 9.02 | 0.86 | 2.13 | 1.54 | 1.80 | 0.07 | 0.08 | 0.19 | 0.57 | 0.76 | 4.47 | 3.71 | 83.00 | 2.58 | 4.45 |
| AB | 21-40 | 6.05 | 4.19 | 0.026 | 0.22 | 10.38 | 1.01 | 0.16 | 2.02 | 2.00 | 0.06 | 0.11 | 0.25 | 0.75 | 1.00 | 5.17 | 4.17 | 80.66 | 1.74 | 4.84 |
| $Bg_1$ | 40-85 | 6.35 | 4.16 | 0.120 | 0.10 | 0.83 | 1.65. | 1.26 | 1.82 | 1.10 | 0.06 | 0.09 | 0.25 | 0.75 | 1.00 | 4.07 | 3.07 | 75.43 | 2.21 | 6.14 |
| $Bg_2$ | 85-138 | 6.07 | 4.33 | 0.019 | 0.08 | 4.21 | 1.76 | 1.76 | 2.11 | 1.20 | 0.07 | 0.11 | 0.22 | 0.66 | 0.88 | 4.37 | 3.49 | 79.86 | 2.51 | 5.03 |
| $Bg_3$ | 138-200 | 5.23 | 4.97 | 0.018 | 0.08 | 4.44 | 1.92 | 0.75 | 1.92 | 1.00 | 0.03 | 0.10 | 0.32 | 0.96 | 1.28 | 4.40 | 3.12 | 70.91 | 1.59 | 7.27 |
| **Mean** | | **6.00** | **4.29** | **0.055** | **0.27** | **5.78** | **1.44** | **0.90** | **1.88** | **1.42** | **0.13** | **0.07** | **0.25** | **0.74** | **0.98** | **4.50** | **3.51** | **77.97** | **2.13** | **5.55** |
| **Terrace (Typic Dystrudept)** | | | | | | | | | | | | | | | | | | | | |
| A | 0-15 | 5.86 | 3.91 | 0.074 | 0.76 | 10.37 | 0.94 | 1.24 | 2.06 | 2.20 | 0.10 | 0.08 | 0.21 | 0.63 | 0.84 | 5.28 | 4.44 | 84.09 | 1.52 | 3.98 |
| AB | 15.40 | 6.45 | 4.28 | 0.025 | 0.38 | 15.20 | 1.48 | 0.08 | 1.92 | 1.30 | 0.17 | 0.08 | 0.14 | 0.42 | 0.56 | 3.93 | 3.87 | 98.47 | 2.04 | 3.56 |
| $Bg_1$ | 40-66 | 6.12 | 4.28 | 0.021 | 0.30 | 14.29 | 0.52 | 0.15 | 1.30 | 2.50 | 0.06 | 0.08 | 0.22 | 0.66 | 0.88 | 4.82 | 3.94 | 81.74 | 1.66 | 4.56 |
| $Bg_2$ | 66-98 | 6.62 | 4.68 | 0.019 | 0.24 | 12.63 | 0.69 | 1.06 | 1.73 | 2.50 | 0.10 | 0.08 | 0.10 | 0.30 | 0.40 | 4.81 | 4.41 | 83.21 | 1.66 | 4.56 |
| $Bg_3$ | 98-200 | 6.43 | 4.83 | 0.017 | 0.23 | 15.53 | 0.67 | 0.86 | 1.68 | 2.50 | 0.07 | 0.09 | 0.15 | 0.45 | 0.60 | 4.94 | 4.34 | 78.62 | 1.82 | 3.04 |
| **Mean** | | **6.36** | **4.40** | **0.031** | **0.38** | **13.58** | **0.86** | **0.68** | **1.74** | **2.20** | **0.07** | **0.08** | **0.16** | **0.49** | **0.65** | **2.91** | **4.20** | **85.23** | **1.74** | **3.44** |
| **Backswamp Soils (Typic Endoaquept)** | | | | | | | | | | | | | | | | | | | | |
| A | 0-4 | 6.44 | 4.35 | 0.037 | 0.09 | 17.07 | 0.96 | 1.48 | 1.92 | 2.00 | 0.10 | 0.07 | 0.03 | 0.09 | 0.12 | 4.21 | 4.09 | 97.15 | 1.66 | 0.71 |
| B | 4-40 | 6.84 | 4.46 | 0.042 | 0.97 | 13.33 | 1.44 | 0.16 | 2.16 | 1.50 | 0.07 | 0.08 | 0.02 | 0.06 | 0.08 | 3.89 | 3.81 | 97.94 | 2.06 | 0.51 |
| C | 84-100 | 6.65 | 4.52 | 0.039 | 0.79 | 0.92 | 0.23 | 0.71 | 1.20 | 1.30 | 0.05 | 0.08 | 0.04 | 0.12 | 0.16 | 2.79 | 2.63 | 94.22 | 2.86 | 1.43 |
| **Mean** | | **6.54** | **4.44** | **0.039** | **0.95** | **14.05** | **0.88** | **0.78** | **1.76** | **1.6** | **0.07** | **0.08** | **0.03** | **0.09** | **0.12** | **3.63** | **3.51** | **96.45** | **2.19** | **0.88** |

## Chemical Characteristics of the Surface Samples in the Study Area

| Replicates | Soil pH in $H_2O$ 1:2.5 | Soil pH in KCL 1:1 | Tot N % | Org Carbon | C/N Ratio | Ca/Mg Ratio | Avail P µg/g | $Ca^{2+}$ | $Mg^{2+}$ | K | $Na^{2+}$ | Exch. $Al^{+}$cmol/kg | Exch. $H^{+}$ Cmol/kg | TEA | ECEC | TEB % | Bs % | Esp % | Al Sat. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ← % → | | | | | | | → Exchangeable Cations Cmol/Kg ← | | | | | | | → % ← | | | | |
| **Levee Crest Soils (Typic Eutrudepts)** | | | | | | | | | | | | | | | | | | | |
| | 6.00 | 3.90 | 0.047 | 0.56 | 1.19 | 0.28 | 0.46 | 1.97 | 0.70 | 0.26 | 0.10 | 0.19 | 0.57 | 0.76 | 3.79 | 3.03 | 79.95 | 2.64 | 5.01 |
| | 6.38 | 3.71 | 0.108 | 0.82 | 7.59 | 11.11 | 0.29 | 1.78 | 1.60 | 0.21 | 0.11 | 0.22 | 0.94 | 1.16 | 4.86 | 3.70 | 76.13 | 2.26 | 4.53 |
| | 6.49 | 5.19 | 0.073 | 0.68 | 9.32 | 2.51 | 0.88 | 3.26 | 1.30 | 0.13 | 0.09 | 0.15 | 0.45 | 0.06 | 5.38 | 4.78 | 88.85 | 1.67 | 2.79 |
| | 5.99 | 4.03 | 0.035 | 0.50 | 14.29 | 1.44 | 1.38 | 1.44 | 1.50 | 0.06 | 0.12 | 0.22 | 0.66 | 0.88 | 4.72 | 3.84 | 81.36 | 2.54 | 4.66 |
| **Mean** | **6.21** | **4.21** | **0.066** | **0.64** | **8.10** | **1.34** | **0.67** | **2.29** | **1.28** | **0.17** | **0.11** | **0.20** | **0.66** | **0.85** | **4.69** | **3.84** | **81.57** | **2.28** | **4.25** |
| **Levee Slope Soils (Typic Dystrudepts)** | | | | | | | | | | | | | | | | | | | |
| | 5.93 | 3.89 | 0.056 | 0.62 | 11.07 | 1.37 | 0.43 | 2.06 | 1.50 | 0.13 | 0.10 | 0.27 | 0.81 | 1.08 | 4.87 | 3.70 | 77.82 | 2.55 | 2.18 |
| | 5.93 | 3.91 | 0.050 | 0.50 | 0.10 | 1.70 | 0.69 | 2.26 | 1.30 | 0.17 | 0.10 | 0.28 | 0.84 | 0.12 | 3.95 | 3.83 | 96.96 | 2.53 | 7.09 |
| | 5.92 | 3.94 | 0.102 | 0.80 | 7.84 | 1.29 | 0.31 | 2.20 | 1.70 | 0.26 | 0.11 | 0.31 | 0.93 | 0.24 | 4.51 | 4.27 | 94.68 | 2.43 | 6.87 |
| | 6.11 | 3.85 | 0.092 | 0.83 | 9.02 | 0.86 | 2.13 | 2.06 | 1.80 | 0.06 | 0.11 | 0.25 | 0.75 | 0.76 | 4.27 | 5.51 | 129.03 | 2.58 | 4.45 |
| **Mean** | **5.97** | **3.90** | **0.075** | **0.69** | **7.01** | **1.31** | **0.89** | **2.21** | **1.20** | **0.16** | **0.11** | **0.28** | **0.83** | **1.55** | **4.40** | **3.85** | **99.61** | **2.53** | **10.15** |
| **Terrace (Typic Dystrudepts)** | | | | | | | | | | | | | | | | | | | |
| | 6.16 | 4.05 | 0.063 | 0.66 | 10.48 | 1.44 | 0.40 | 2.16 | 1.50 | 0.10 | 0.10 | 0.18 | 0.36 | 0.48 | 4.40 | 3.92 | 89.09 | 2.27 | 4.09 |
| | 5.65 | 3.94 | 0.110 | 0.86 | 7.82 | 21.1 | 1.45 | 2.11 | 0.10 | 0.10 | 0.10 | 0.12 | 0.60 | 0.80 | 3.21 | 2.41 | 75.08 | 3.12 | 6.23 |
| | 6.05 | 4.04 | 0.043 | 0.42 | 9.77 | 2.27 | 1.24 | 2.50 | 1.10 | 0.17 | 0.09 | 0.20 | 0.87 | 0.16 | 4.02 | 3.86 | 96.02 | 2.24 | 7.21 |
| | 5.86 | 3.91 | 0.074 | 0.76 | 10.27 | 0.94 | 1.24 | 2.06 | 2.20 | 0.10 | 0.08 | 0.29 | 0.63 | 0.84 | 5.28 | 4.44 | 84.09 | 1.52 | 3.98 |
| **Mean** | **5.85** | **3.99** | **0.073** | **0.68** | **9.58** | **6.44** | **0.82** | **2.21** | **1.23** | **0.09** | **0.09** | **0.21** | **0.62** | **0.57** | **4.23** | **3.66** | **86.06** | **2.29** | **5.38** |
| **Backswamp Soils (Typic Endoaquept)** | | | | | | | | | | | | | | | | | | | |
| | 5.91 | 3.91 | 0.114 | 1.40 | 12.28 | 0.99 | 0.34 | 1.78 | 1.80 | 0.13 | 0.12 | 0.22 | 0.66 | 0.88 | 4.71 | 3.83 | 81.32 | 2.54 | 4.67 |
| | 6.10 | 3.93 | 0.056 | 1.59 | 10.54 | 0.95 | 0.56 | 1.52 | 1.60 | 0.21 | 0.09 | 0.02 | 0.06 | 0.08 | 3.50 | 3.42 | 97.71 | 2.57 | 0.57 |
| | 6.37 | 4.52 | 0.064 | 1.67 | 10.47 | 1.09 | 0.68 | 1.63 | 1.50 | 0.13 | 0.08 | 0.20 | 0.06 | 0.08 | 4.14 | 3.34 | 80.68 | 1.93 | 4.83 |
| | 6.47 | 4.35 | 0.037 | 1.63 | 17.03 | 0.96 | 1.48 | 1.92 | 2.00 | 0.10 | 0.07 | 0.03 | 0.09 | 0.12 | 4.21 | 4.09 | 97.15 | 1.66 | 0.71 |
| **Mean** | **6.21** | **4.23** | **0.82** | **1.27** | **12.58** | **1.00** | **0.77** | **1.71** | **1.73** | **0.14** | **0.09** | **0.12** | | | | | | | |

pH (KCL)= pH in Potassium Chloride pH ($H_2O$) = pH in water, OC = Organic carbon, TN = Total Nitrogen, Avail. P = Available Phosphorus, $Mg^{2+}$ = magnesium ion, $Na^{+}$ = sodium ion, $K^{+}$ potassium ion, $Ca^{2+}$:$Mg^{2+}$ = calcium magnesium ion ratio, TEB = Total Exchangeable Bases, $AL^{3+}$ + $H^{+}$ = aluminium hydrogen ion summation, $AL^{3+}$ = aluminium concentration, ECEC-Effective Cation Exchange Capacity, Al.sat =

## Table 4.5: Mean Values of Physical and Chemical Characteristics of Soils in the Study Area

| Land Quality/Characteristics | Units | Levee Crest | | Levee Slope | | Terrace | | Backswamp | |
|---|---|---|---|---|---|---|---|---|---|
| | | **EO1** | **EOS** | **EO2** | **EO2S** | **EO3** | **EO3S** | **EO4** | **EO4S** |
| pH in $H_2O$ | - | 6.31 | 6.21 | 6.00 | 5.97 | 6.36 | 5.85 | 6.54 | 6.21 |
| pH in KCL | - | 4.20 | 4.21 | 4.29 | 3.90 | 4.40 | 3.99 | 4.44 | 4.23 |
| Total Nitrogen | % | 0.022 | 0.066 | 0.055 | 0.075 | 0.031 | 0.073 | 0.039 | 0.068 |
| O Carbon | % | 0.34 | 0.64 | 0.27 | 0.69 | 0.38 | 0.68 | 0.55 | 0.82 |
| C/N Ratio | % | 15.53 | 8.10 | 5.78 | 7.01 | 13.58 | 9.58 | 14.05 | 12.58 |
| Ca/Mg Ratio | Cmol/kg | 0.96 | 1.34 | 1.44 | 1.31 | 0.86 | 6.44 | 0.88 | 1.00 |
| Available P | m/kg | 0.50 | 0.67 | 1.29 | 0.89 | 0.68 | 0.82 | 0.78 | 0.77 |
| Ca | Cmol/kg | 1.60 | 2.29 | 1.88 | 2.21 | 1.74 | 2.21 | 1.76 | 1.71 |
| Mg | Cmol/kg | 1.70 | 1.28 | 1.42 | 1.20 | 2.20 | 1.23 | 1.6 | 1.73 |
| K | Cmol/kg | 0.05 | 0.17 | 0.13 | 0.16 | 0.07 | 0.09 | 0.07 | 0.14 |
| Na | Cmol/kg | 0.11 | 0.11 | 0.07 | 0.11 | 0.08 | 0.09 | 0.08 | 0.09 |
| Exch. Al | Cmol/kg | 0.19 | 0.20 | 0.25 | 0.28 | 0.16 | 0.21 | 0.03 | 0.12 |
| Exch . H | Cmol/kg | 0.56 | 0.66 | 0.74 | 0.83 | 0.49 | 0.62 | 0.09 | 0.35 |
| EA | Cmol/kg | 0.75 | 0.85 | 0.98 | 1.55 | 0.65 | 0.57 | 0.12 | 0.47 |
| CEC | Cmol/kg | 1.76 | 1.84 | 2.31 | 2.39 | 2.41 | 2.43 | 2.51 | 2.59 |
| ECEC | Cmol/kg | 4.20 | 4.69 | 4.50 | 4.40 | 4.76 | 4.23 | 3.63 | 4.14 |
| TEB | % | 3.58 | 3.84 | 3.51 | 3.85 | 4.20 | 3.66 | 3.51 | 3.67 |
| BS | % | 84.84 | 81.57 | 77.97 | 99.61 | 85.23 | 86.06 | 96.45 | 89.22 |
| ESP | % | 2.11 | 2.28 | 2.13 | 2.53 | 1.74 | 2.29 | 2.19 | 2.18 |
| Al .Sat | % | 4.54 | 4.25 | 5.35 | 10.15 | 3.44 | 5.38 | 0.88 | 2.70 |
| Sand | g/kg | 922.1 | 871.0 | 880.0 | .896.0 | 931.8 | 911.0 | 889.3 | 861.0 |
| Silt | g/kg | 16.0 | 16.0 | 16.0 | 16.0 | 16.0 | 16.0 | 16.0 | 16.0 |
| clay | g/kg | 63.0 | 113.0 | 60.0 | 88.0 | 52.0 | 73.0 | 63.0 | 123.0 |
| Porosity | % | 533.2 | 416.8 | 550.2 | 402.1 | 561.5 | 357.2 | 539.6 | 416.8 |
| Bulk density | $mg/m^3$ | 1.23 | 1.09 | 1.19 | 0.99 | 1.16 | 0.94 | 1.22 | 1.09 |
| Moisture Content | % | 8.32 | 8.20 | 9.23 | 8.02 | 9.86 | 9.52 | 24.65 | 23.83 |

EO1 = Levee Crest Profile Samples; EO2 = Levee Slope Profile Sample; EO3 = Terrace Profile Samples, EO4 = Backswamp profile Samples

EO1S = Levee Crest Surface Samples; EO2S = Levee Slope Surface Samples; EO3S = Terrace Surface Samples; EO4 = Backswamp Surface Samples

## 4.4 Soil Classification

Table 4.6 shows the taxonomic classification of soils in the study area. Based on data from laboratory analysis (chemical and physical properties) and field observation (morphological properties) Soils fell into the order of Inceptisols and Entisols of the USDA soil taxonomy (Soil Survey Staff, 2010). Soils in levee crest (EO1) were classified into suborder Udepts, great group Eutrudepts, and into sub group Typic Eutrudepts.Soils in levee slope (EO2) and terrace (EO3) were classified into suborder Udults, great group Endoaquults, and into subgroup Typic Hapludult (Soil Survey Staff 2010). However, Soils of backswamp (EO4) were classified into suborder 'Aquepts' and great group Endoaquepts, subgroup TypicEndoaquepts(Soil SurveyStaff2010).

These soils were also classified according to FAO/UNESCO legend as Eutric Cambisols, levee crest (EO1), whilelevee slope (EO2) - terrace (EO3) were classifiedas Haplic Cambisol, However, backswamp (EO4) were classified as Eutric Fluvisols (FAO/UNESCO, 2006.)

**Table 4.6: Taxonomic Classification of Soils in the Study Area**

| Geomorphic Or Mapping units | | | USDA | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **Pedon** | **Drainage** | **Order** | **Suborder** | **Great group** | **Subgroup** | **Family** | **FAO/UNESCO** |
| Levee Crest | EO1 | WD | Inceptisol | Udepts | Eutrudepts | Typic Eutrudepts | Coarse over loamy, mixed udic, iso-hyperthermic | Eutric Cambisol |
| Levee Slope | EO2 | MWD | Inceptisol | Udults | Hapludults | Typic Hapludults | Coarse- loamy over sandy mixed udic, iso-hyperthermic, | HaplicCambisol |
| Terrace | EO3 | PD | Inceptisol | Udults | Hapludults | Typic Hapludults | Coarse- loamy, mixed, aquic, iso-hyperthermic | HaplicCambisol |
| Backswamp | EO4 | VPD | Entisols | Aquepts | Endoaquepts | Typic Endoaquepts | Loamy, mixed, aquic, iso-hyperthermic | Eutric Fluviisol |

WD = Well Drained; MWD = Moderately Well Drained; PD = Poorly Drained; VPD = Very Poorly Drained.

## 4.5 Land Evaluation

### 4.5.1 Land Capability Classification

The land capability classification of the mapping units showing the class and subclasses (limitations) is presented in Table 4.7.

Out of the eight land capability classes in this system, only four (classes II, III, IV, and V) were encountered in the study area. Soil pedons and surface soil sampleslevee crest (EO1, EO1S) and levee slope (EO2 EO2S), fell into land capability classes II while levee crest(EO1,EO1S) has nutrient or fertility as limitation, levee slope (EO2, EO2S) have both 'w' (wetness and nutrient or fertility) as limitation. Terrace, pedon and surface sample(EO3, EO3S) fell into land capability classes III, the pedon had 'w' (wetness) and 'n' (nutrient or fertility) as limitations. Backswamp pedon and surface sample(EO4,EO4S) fell into land capability classes v and the pedon has 'w', (wetness) 'n' (nutrient or fertility) and 'a' (angle of slope)as limitations

## Table 4.7 Land Capability Classification/Evaluation of the Pedons in the Study Area

| Mapping Units | | Class | | | | | | | | | Capability Group | Recommended Agricultural Practices |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Arable Class | | | | Non Arable Class | | Sub Class | | | | |
| | Pedons | II | III | IV | V | a | t | w | n | | | |
| Levee Crest | EO1 | + | - | - | - | - | - | - | - | + | IIn | Cassava, Maize, Yam, Plantain, Vegetables, Pineapples, beans |
| Levee Slope | EO2 | - | + | - | - | - | - | - | - | + | IIIwn | Groundnut, plantain, Yam, Pineapples, Potatoes, Cassava, Maize |
| Terrace | EO3 | - | | + | - | - | - | - | + | + | IVwn | Sugarcane, Plantain, Banana, Cocoyam |
| Back Farming Swamp | EO4 | - | - | - | + | - | - | - | + | + | Vwna | Cocoyam, Fish |

KEY:

a = Angle of Slope
t = Soil Texture
w = Wetness
n = Nutrient or Fertility

### 4.5.2 Fertility Capability Classification (FCC)

The conversion table used in evaluating the fertility status of the soils is shown in Appendix 8, while Fertility capability classification units or classes are shown in Table 4.8

The soils in Levee Crest (EO1,EO1S) are classified as Lhk, the Levee slope soil (EO2,EO2S) were classified as Lhk, Terrace soil (EO3,EO3S) are classified as Lhk, while the Backswamp soils (EO4,EO4S) was classified as Lghk. The soilson levee crest - backswamp pedons EO1-EO4 including surface samples EO1S-EO4S had loamy top and subsoil -"Type", "substrata type" (i.e. clay <35%) as represented by 'L' the constraints were slightly acidic (i.e. below 10% Al-saturation of the ECEC within 50cm of soil surface) as represented by 'h' ("modifier") and low potassium reserves (i.e. exchangeable K <0.2/cmol/kg) as represented by 'K' ("modifier"). EO4, EO4S had acid as constraint. Gley (i.e. soils saturated with water for > 60 days in moist years) as represented by 'g' acid (h) and low potassium reserves (k) was the constraint.

**Table 4.8 Fertility Capability Classification/Evaluation of Soils in the Study Area (pedon)**

| Mapping Units | Soils | Type | Substrata type | g | h | k | FCC Unit |
|---|---|---|---|---|---|---|---|
| Levee crest | EO1 | L | L | - | + | + | Lhk |
| Levee Slope | EO2 | L | L | - | + | + | Lhk |
| Terrace | EO3 | L | L | - | + | + | Lhk |
| Backswamp | EO4 | L | L | + | + | + | Lghk |

**KEY:**

l = Loamy
c = Clay
g = Gley
h = Acid
k = Low potassium Reserve

**Fertility Capability Classification/Evaluation of Soils in the Study Area (Surface soil samples)**

| Mapping Units | Soils | Type | Substrata type | g | h | k | FCC Unit |
|---|---|---|---|---|---|---|---|
| Levee crest | EO1 | L | L | - | + | + | Lhk |
| Levee Slope | EO2 | L | L | - | + | + | Lhk |
| Terrace | EO3 | L | L | - | + | + | Lhk |
| Backswamp | EO4 | L | L | + | + | + | Lghk |

**KEY:**

l = Loamy
c = Clay
g = Gley
h = Acid
k = Low potassium Reserve

### 4.5.3 Land Suitability Classification

The land qualities/characteristics (Table 4.9) of the mapping units (levee crest, levee slope, terrace, and backswamp) were matched with the ratings of land qualities representing soil conditions for rice, cassava, maize and sugarcane(Table 3.3, 3.4, 3.5 and 3.6).

Land suitability classification of the soils for wetland/swamp rice, cassava maize and sugarcane production are shown in Tables 4.9, 4.10, 4.11 and 4.12.

The soils of levee crest- backswamp pedonsEO1-EO4 and surface samples EO1S-EO4S have low or marginal suitability (S3) for swamp rice production.The unsuitability of the area was in agreement with Olaleye *et al.,(*2008)who assessed representative pedons used for rice cultivation and reported marginal (S3) to unsuitable (N1). The major constraints they identified in the pedons were poor soil texture, which translates to poor water management coupled with suboptimal nutrient contents (i.e., available Phosphorus, exchangeable potassium K, and cation exchange capacity, which may predispose rice plants to excessive $Fe^{2+}$ uptake (or bronzing or yellowing symptoms).

While the land suitability classification for cassava production showed that soils of EO1-EO3, EO1S-EO2S have moderate suitability (S2) for cassava production, EO3, have moderate or medium suitability (S2) while EO3S has low or marginal suitability. EO4, EO4S have low or marginal suitability (S3) for cassava production. However, soils of EO1-EO4, EO1S-EO3S showed moderate or medium suitability(S2) for maize production while EO4S showed low suitability for maize production.The soils of levee crest- backswamp pedons EO1-EO4 and surface samples EO1S-EO4S have medium or moderate suitability (S2) for sugarcane production.

The major limitations are soil texture and structure, which directly affect water-holding capacity, permeability of the soil and other physical properties. Other limiting factors are soil fertility, measured by CEC, organic matter and total nitrogen content.

## Table 4.9: Land Suitability Classification of the Soils in the Study Area for Wetland or Swamp Rice Production

| | | | | | | Levee Crest (EO1) | | | | | Land Quality |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Land | Unit | wt | High | Moderate | | Low | Very Low | | | | |
| Characteristics | | | | | (S1) | (S2) | | (S3) | (N1) | | |
| | | | | 3 | 2 | | 1 | 0 | | | |
| Land quality score | | | | 4 | | | | | | | |
| Fertility Status | Organic carbon | % | | 1 | - | - | | - | 0 | | |
| | Tot Nitrogen | % | | 1 | - | - | | - | - | | |
| | Avail.P | µg/g | | 1 | - | - | | - | 0 | | |
| | Exch. K | Cmol/kg | | 1 | - | - | | - | - | | |
| | Exch.Ca | Cmol/kg | | 1 | - | - | | 1 | - | | |
| | pH | - | | 1 | 3 | - | | - | - | | |
| | Base Saturation | % | | 1 | 3 | - | | - | - | | |
| Workability | | | | | | | | | | | |
| | Soil Consistence | | | | | | | | | | |
| | Moist | - | | 1 | - | - | | - | 0 | | |
| | Wet | - | | 1 | - | - | | - | - | | |
| Toxicity | | | | 4 | | | | | | | |
| | ESP | % | | 2 | 6 | - | | - | 0 | | |
| Wetness | | | | | | | | | | | |
| | | | | 6 | | | | | | | |
| | Drainage Class | - | | 3 | - | - | | - | 0 | | |
| | Flood Duration | Months | | 2 | - | - | | - | 0 | | |
| | Ground $H_2O$ table | cm | | 3 | - | - | | - | 0 | | |
| Climate | | | | | | | | | | | |
| | Annual Rainfall | mm | | 2 | 6 | - | | - | - | | |
| Soil Physical condition | | | | 4 | | | | | | | |
| | Text Class | - | | 3 | - | - | | - | | | |
| | Soil depth | cm | | 3 | 9 | - | | - | - | | |
| | Clay | % | | 2 | - | - | | - | - | | |
| Land Suitability | Sub-total | | | 27 | - | | 1 | 0 | | | |
| Obtained land quality index | | | | | | | | | | | |
| | Grand total | | | | | | 28 | | | | |
| Expected land quality | Index range | | | >75 | 50-75 | | 20-50 | <20 | | > | |

S1 = High Suitability

S2 = Moderate or Medium Suitability

S3 = Low or Marginal Suitability

N1 = Very Low or not Suitable

## Land Suitability Classification of Soils in the Study Area for Wetland or Swamp Rice Production

**Levee Slope (EO2)**

| Land Quality | Land Characteristics | Unit | wt | High (S1) | Moderate (S2) | | Low (S3) | Very Low (N1) |
|---|---|---|---|---|---|---|---|---|
| | | | 3 | 2 | | 1 | 0 | |
| Land quality score | | | 4 | | | | | |
| Fertility Status | Organic carbon | % | 1 | - | - | | - | 0 |
| | Tot Nitrogen | % | 1 | - | - | | - | 0 |
| | Avail.P | µg/g | 1 | - | - | | 1 | - |
| | Exch. K | Cmol/kg | 1 | - | 2 | | - | - |
| | Exch.Ca | Cmol/kg | 1 | - | - | | 1 | - |
| | pH | - | 1 | 3 | - | | - | - |
| | Base Saturation | % | 1 | 3 | - | | - | - |
| Workability | | | | | | | | |
| | Soil Consistence | | | | | | | |
| | Moist | - | 1 | - | - | | 1 | 0 |
| | Wet | - | 1 | - | - | | 1 | - |
| Toxicity | | | | | | | | |
| | ESP | % | 2 | 6 | - | | 0 | - |
| Wetness | | | | | | | | |
| | | | 6 | | | | | |
| | Drainage Class | - | 3 | - | - | | - | 0 |
| | Flood Duration | Months | 2 | - | - | | - | 0 |
| | Ground $H_2O$ table | cm | 3 | - | - | | - | 0 |
| Climate | | | | | | | | |
| | Annual Rainfall | mm | 2 | 6 | - | | - | - |
| Soil Physical condition | | | 4 | | | | | |
| | Textural Class | - | 3 | - | - | | 3 | - |
| | Soil depth | cm | 3 | 9 | - | | - | - |
| | Clay | % | 2 | - | - | | - | - |
| Land Suitability | Sub-total | | 33 | 2 | | 9 | 0 | |
| Obtained land quality index | | | | | | | | |
| | Grand total | | | | | 44 | | |
| Expected land quality | Index range | | >75 | 50-75 | | 20-50 | <20 | |

S1 = High Suitability

S2 = Moderate or Medium Suitability

S3 = Low or Marginal Suitability

N1 = Very Low or not Suitable

## Land Suitability Classification of Soils the Study Area for Wetland or Swamp Rice Production

**Terrace (EO3)**

| Land Quality | Land Characteristics | | Unit | wt (S1) | High (S2) | Moderate | (S3) | Low (N1) | Very Low |
|---|---|---|---|---|---|---|---|---|---|
| | Land quality score | | | 4 | 3 | 2 | | 1 | 0 |
| Fertility Status | Organic carbon | | % | 1 | - | - | | - | - |
| | Tot Nitrogen | | % | 1 | 3 | - | | - | 0 |
| | Avail.P | | µg/g | 1 | - | - | | - | 0 |
| | Exch. K | | Cmol/kg | 1 | - | - | | 1 | - |
| | Exch.Ca | | Cmol/kg | 1 | - | - | | - | 0 |
| | pH | - | | 1 | 3 | - | | - | - |
| | Base Saturation | | % | 1 | 3 | - | | - | - |
| Workability | Soil Consistence | | | | | | | | |
| | Moist | | - | 1 | - | - | | 1 | - |
| | Wet | | - | 1 | - | - | | 1 | - |
| Toxicity | ESP | | % | 2 | - | - | | - | 0 |
| Wetness | | | | | 6 | | | | |
| | Drainage Class | - | | 3 | - | 6 | | - | - |
| | Flood Duration | Months | | 2 | - | 4 | | - | 0 |
| | Ground $H_2O$ table | cm | | 3 | 9 | - | | - | - |
| Climate | Annual Rainfall | mm | | 2 | 6 | - | | - | - |
| Soil Physical condition | | | | 4 | | | | | |
| | Textural Class | - | | 3 | - | - | | 3 | - |
| | Soil depth | cm | | 3 | 9 | - | | - | - |
| | Clay | % | 2 | - | | | - | 0 | |
| Land Suitability | Sub-total | | 33 | 10 | | 6 | - | | |
| Obtained land quality index | | | | | | | | | |
| | Grand total | | | | | 49 | | | |
| Expected land quality | Index range | | >75 | 50-75 | | 20-50 | <20 | | |

S1 = High Suitability

| | | |
|---|---|---|
| S2 | = | Moderate or Medium Suitability |
| S3 | = | Low or Marginal Suitability |
| N1 | = | Very Low or not Suitable |

## Land Suitability Classification of Soils in the Study Area for Wetland or Swamp Rice Production

**Backswamp (EO4)**

| | Land Quality | | Land | Unit | wt | High | Moderate | | Low | Very Low |
|---|---|---|---|---|---|---|---|---|---|---|
| Characteristics | | | | | | (S1) | (S2) | | (S3) | (N1) |
| | | | | | 3 | 2 | | 1 | 0 | |
| Land quality score | | | | | 4 | | | | | |
| Fertility Status | | Organic carbon | | % | 1 | - | - | | - | 0 |
| | | Tot Nitrogen | | % | 1 | 3 | - | | - | - |
| | | Avail.P | | µg/g | 1 | - | - | | - | 0 |
| | | Exch. K | | Cmol/kg | 1 | 3 | - | | - | - |
| | | Exch.Ca | | Cmol/kg | 1 | - | - | | 1 | - |
| | | pH | | - | 1 | - | - | | 1 | - |
| | | Base Saturation | | % | 1 | 3 | - | | - | - |
| | | Workability | | | | | | 2 | | |
| | | Soil Consistence | | | | | | | | |
| | | Moist | | - | 1 | - | - | | 1 | - |
| | | Wet | | - | 1 | - | - | | 1 | - |
| | | Toxicity | | | | | | | | |
| | | ESP | | % | 2 | - | - | | - | 0 |
| | | Wetness | | | | | | | | |
| | | | | 6 | | | | | | |
| | Drainage Class | | - | 3 | - | - | - | 3 | - | |
| Flood Duration | Months | | | | 2 | 6 | - | | - | - |
| | Ground $H_2O$ table | | cm | 3 | - | 6 | | - | - | |
| | Climate | | | | | | | | | |
| | Annual Rainfall | | mm | 2 | 6 | - | | - | - | |
| Soil Physical condition | | | | | 4 | | | | | |
| | Textural Class | | - | 3 | - | - | | 3 | - | |
| | Soil depth | | cm | 3 | - | - | | 3 | - | |
| | Clay | | % | 2 | - | - | | - | 0 | |
| Land Suitability | Sub-total | | | | 20 | 6 | | 17 | - | |
| Obtained land quality index | | | | | | | | | | |
| Grand total | | | | | | 43 | | | | |
| Expected land quality Index range | | | | | >75 | 50-75 | | 20-50 | <20 | |

| | | |
|---|---|---|
| S1 | = | High Suitability |

| | | |
|---|---|---|
| S2 | = | Moderate or Medium Suitability |
| S3 | = | Low or Marginal Suitability |
| N1 | = | Very Low or not Suitable |

## Table 4.10 Land Suitability Classification of Soils in the Study Area for Cassava Production

| | | | | Levee Crest (EO1) | | | |
|---|---|---|---|---|---|---|---|
| Land Quality | Land Characteristics | Unit | wt | High | Moderate | Low | Very Low |
| | | | (S1) | (S2) | (S3) | (N1) | |
| | | | | 3 | 2 | 1 | 0 |
| Land quality score | | | 4 | | | | |
| Fertility Status | Organic carbon | % | 1 | - | - | - | 0 |
| | Tot Nitrogen | % | 1 | 3 | - | - | - |
| | Avail.P | µg/g | 1 | - | - | 1 | - |
| | Exch. K | Cmol/kg | 1 | - | - | 0 | - |
| | pH | - | 1 | 3 | - | - | - |
| | Base Saturation | % | 1 | 3 | - | - | - |
| Workability | | | 6 | | | | |
| | Soil Consistence | | | | | | |
| | Dry | - | 2 | 6 | - | - | - |
| | Moist | - | 2 | 6 | - | - | - |
| | wet | 2 | - | 4 | - | - | - |
| Drainage | | | 6 | | | | |
| | Drainage Class | - | 3 | 9 | - | - | - |
| | Porosity | % | 2 | - | - | 2 | 0 |
| Abundant/cm$^2$ | | | | | | | |
| | Ground $H_2O$ table | cm | 3 | 9 | - | - | - |
| Avail. Water | | | 5 | | | | |
| | Text. Class | - | 3 | - | 6 | - | - |
| Rooting Depth | | | 4 | | | | |
| | Soil depth | cm | 3 | 9 | - | - | - |
| Land Suitability | Sub-total | | | 48 | 10 | 3 | - |
| Obtained land quality index | | | | | | | |
| | Grand total | | | | 61 | | |
| Expected land quality | Index range | | | >80 | 40-80 | 20-40 | >20 |

| | | |
|---|---|---|
| S1 | = | High Suitability |
| S2 | = | Moderate or Medium Suitability |

S3 = Low or Marginal Suitability
N1 = Very Low or not Suitable

## TABLE 4.10Land Suitability Classification of Soils in the Study Area for Cassava Production

**Levee Slope (EO2)**

| Land Quality | Land Characteristics | Unit | wt | High (S1) | Moderate (S2) | Low (S3) | Very Low (N1) |
|---|---|---|---|---|---|---|---|
| | | | | 3 | 2 | 1 | 0 |
| Land quality score | | | 4 | | | | |
| Fertility Status | Organic carbon | % | 1 | - | - | - | 0 |
| | Tot Nitrogen | % | 1 | 3 | - | - | - |
| | Avail.P | µg/g | 1 | - | - | - | 0 |
| | Exch. K | Cmol/kg | 1 | - | - | - | 0 |
| | pH | - | 1 | - | 2 | - | - |
| | Base Saturation | % | 1 | 3 | - | - | - |
| Workability | | | 6 | | | | |
| Soil Consistence | | | | | | | |
| | Dry | - | 2 | - | 4 | - | - |
| | Moist | - | 2 | - | 4 | - | - |
| | Wet | | 2 | - | 4 | - | - |
| Drainage | | | 6 | | | | |
| | Drainage Class | - | 3 | 9 | - | - | - |
| | Porosity | % | 2 | - | - | 2 | 0 |
| | Abundant/cm$^2$ | | | | | | |
| | Ground $H_2O$ table | cm | 3 | 9 | - | - | - |
| Avail. Water | | | 5 | | | | |
| | Text.Class | - | 3 | - | - | - | 0 |
| Rooting Depth | | | 4 | | | | |
| Soil depth | cm 3 9 | - | | - | - | | |
| Land Suitability | Sub-total | | | 33 | 14 | 2 | - |
| Obtained land quality index | | | | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Grand total | | | | 54 | | |
| Expected land quality | Index range | | | >80 | 40-80 | 20-40 | >20 |

S1 = High Suitability
S2 = Moderate or Medium Suitability
S3 = Low or Marginal Suitability
N1 = Very Low or not Suitable

## Land Suitability Classification of Soils in the Study Area for Cassava Production

| | | | | Terrace (EO3) | | | |
|---|---|---|---|---|---|---|---|
| Land Quality | Land Characteristics | Unit | wt | High (S1) | Moderate (S2) | Low (S3) | Very Low (N1) |
| | | | | 3 | 2 | 1 | 0 |
| Land quality score | | | 4 | | | | |
| Fertility Status | Organic carbon | % | 1 | - | - | - | 0 |
| | Tot Nitrogen | % | 1 | 3 | - | - | - |
| | Avail.P | µg/g | 1 | - | - | - | 0 |
| | Exch. K | Cmol/kg | 1 | - | - | - | 0 |
| | pH | - | 1 | - | 2 | - | - |
| | Base Saturation | % | 1 | 3 | - | - | - |
| Workability | | | 6 | | | | |
| | Soil Consistence | | | | | | |
| | Dry | - | 2 | - | 4 | - | - |
| | Moist | - | 2 | - | 4 | - | - |
| | Wet | | 2 | - | 4 | - | - |
| Drainage | | | 6 | | | | |
| | Drainage Class | - | 3 | - | - | 3 | - |
| | Porosity | % | 2 | - | - | 2 | - |
| | Abundant/$cm^2$ | | | | | | |
| | Ground $H_2O$ table | cm | 3 | 9 | - | - | - |
| Avail. Water | | | 5 | | | | |
| | Text.Class | - | 3 | - | - | - | 0 |
| Rooting Depth | | | 4 | | | | |
| | Soil depth | cm | 3 | 9 | - | - | - |
| Land Suitability | Sub-total | | | 24 | 12 | 5 | - |
| Obtained land quality index | | | | | | | |
| | Grand total | | | | 42 | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Expected land quality | Index range | | | >80 | 40-80 | 20-40 | >20 |

S1 = High Suitability
S2 = Moderate or Medium Suitability
S3 = Low or Marginal Suitability
N1 = Very Low or not Suitable

## Land Suitability Classification of Soils in the Study Area for Cassava Production

| Backswamp (EO4) | | | | | | | |
|---|---|---|---|---|---|---|---|
| Land Quality | Land Characteristics | Unit | wt | High (S1) | Moderate (S2) | Low (S3) | Very Low (N1) |
| | | | | 3 | 2 | 3 | 0 |
| Land quality score | | | 4 | | | | |
| Fertility Status | Organic carbon | % | 1 | - | - | 1 | - |
| | Tot Nitrogen | % | 1 | 3 | - | - | - |
| | Avail.P | µg/g | 1 | - | - | - | 0 |
| | Exch. K | Cmol/kg | 1 | - | - | - | 0 |
| | pH | - | 1 | 3 | - | | |
| | Base Saturation | % | 1 | 3 | - | - | - |
| Workability | | | 6 | | | | |
| | Soil Consistence | | | | | | |
| | Dry | - | 2 | - | 4 | - | - |
| | Moist | - | 2 | - | - | 2 | - |
| | Wet | | 2 | - | - | 2 | - |
| Drainage | | | 6 | | | | |
| | Drainage Class | - | 3 | - | - | - | 0 |
| | Porosity | % | 2 | - | - | 2 | - |
| | Abundant/cm$^2$ | | | | | | |
| | Ground $H_2O$ table | cm | 3 | - | - | - | 0 |
| Avail. Water | | | 5 | | | | |
| | Text.Class | - | 3 | - | - | - | 0 |
| Rooting Depth | | | 4 | | | | |
| | Soil depth | cm | 3 | - | 6 | - | - |
| Land Suitability | Sub-total | | | 9 | 10 | 9 | - |
| Obtained land quality index | | | | | | | |
| Grand total | | | | 28 | | | |

| | | | | | |
|---|---|---|---|---|---|
| Expected land quality | Index range | >80 | 40-80 | 20-40 | >20 |

S1 = High Suitability
S2 = Moderate or Medium Suitability
S3 = Low or Marginal Suitability
N1 = Very Low or not Suitable

## Table 4.11 Land Suitability Classification of Soils in the Study Area for Maize Production

| | | | | **Levee Crest (EO1)** | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Land Quality | Land Characteristics | Unit | wt | High (S1) | Moderate (S2) | | Low (S3) | Very Low (N1) | |
| | | | | 3 | 2 | | 1 | 0 | |
| Land quality score | | | 4 | | | | | | |
| Fertility Status | Organic Carbon | % | 1 | - | - | | - | 0 | |
| | Ca | Cmol/kg | 1 | - | - | | | | |
| | Avail.P | µg/g | 1 | - | - | | 1 | - | |
| | Exch. K | Cmol/kg | 1 | - | - | | - | 0 | |
| | pH | - | 1 | 3 | - | - | - | - | |
| | Base Saturation | % | 1 | 3 | - | | - | - | |
| Workability | | | 6 | | | | | | |
| | Soil Consistence | | | | | | | | |
| | Dry | - | 2 | - | 4 | | - | - | |
| | Moist | - | 2 | 6 | - | | - | - | |
| | Wet | | 2 | | 4 | | - | | - |
| Drainage | | | 6 | | | | | | |
| | Drainage Class | - | 3 | 9 | - | | - | - | |
| | Porosity | % | 2 | - | - | | 2 | - | |
| | Abundant/$cm^2$ | | | | | | | | |
| | Ground $H_2O$ table | cm | 3 | 9 | - | | - | - | |
| | Avail. Water | | 5 | | | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Text. Class | - | 3 | - | 6 | - | - |
| Rooting Depth | | | 4 | | | | |
| | Soil depth | cm | 3 | 9 | - | - | - |
| Land Suitability Sub -total | | | | 36 | 14 | 4 | 0 |
| obtained Land Quality Index Grand Total | | | | | 54 | | |
| Ideal Index of soil condition for Maize production | | | | >80 | 40-80 | 20-40 | >20 |

S1 = High Suitability
S2 = Moderate or Medium Suitability
S3 = Low or Marginal Suitability
N1 = Very Low or not Suitable

## Land Suitability Classification of Soils in the Study Area for Maize Production

**Levee Slope (EO2)**

| Land Quality | Land Characteristics | Unit | wt | High (S1) | Moderate (S2) | | Low (S3) | Very Low (N1) |
|---|---|---|---|---|---|---|---|---|
| | | | | 3 | 2 | | 1 | 0 |
| Land quality score | | | 4 | | | | | |
| Fertility Status | Organic Carbon | % | 1 | - | - | | - | 0 |
| | Ca | cmol/kg | 1 | - | - | | 1 | - |
| | Avail.P | µg/g | 1 | - | - | | - | 0 |
| | Exch. K | Cmol/kg | 1 | - | - | | - | 0 |
| | pH | - | 1 | - | 2 | | - | - |
| | Base Saturation | % | 1 | 3 | - | | - | - |
| Workability | | | 6 | | | | | |
| | Soil Consistence | | | | | | | |
| | Dry | - | 2 | - | 4 | | - | - |
| | Moist | - | 2 | - | 4 | | - | - |
| | Wet | | 2 | - | 4 | - | - | - |
| Drainage | | | 6 | | | | | |
| | Drainage Class | - | 3 | 9 | - | | - | - |
| | Porosity | % | 2 | - | - | | 2 | - |
| | Abundant/cm$^2$ | | | | | | | |
| | Ground $H_2O$ table | cm | 3 | 9 | - | | - | - |
| Avail. Water | | | 5 | | | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Text. Class | - | 3 | - | 6 | - | - | |
| Rooting Depth | | | 4 | | | | | |
| | Soil depth | cm | 3 | 9 | - | - | - | - |
| Land Suitability Sub -total | | | | 30 | 20 | 3 | 0 | |
| obtained Land Quality Index Grand Total | | | | | 53 | | | |
| Ideal Index of soil condition for Maize production | | | | >80 | 40-80 | 20-40 | >20 | |

S1 = High Suitability
S2 = Moderate or Medium Suitability
S3 = Low or Marginal Suitability
N1 = Very Low or not Suitable

## Suitability Classification of Soils in the Study Area for Maize Production

**Terrace (EO3)**

| Land Quality | Land Characteristics | Unit | wt | High (S1) | Moderate (S2) | Low (S3) | Very Low (N1) |
|---|---|---|---|---|---|---|---|
| | | | | 3 | 2 | 1 | 0 |
| Land quality score | | | 4 | | | | |
| Fertility Status | Organic Carbonr | % | 1 | - | - | - | 0 |
| | Ca | cmol/kg | 1 | - | - | 1 | - |
| | Avail.P | µg/g | 1 | - | - | - | 0 |
| | Exch. K | Cmol/kg | 1 | - | - | - | 0 |
| | pH | - | 1 | 3 | - | - | - |
| | Base Saturation | % | 1 | 3 | - | - | - |
| Workability | | | 6 | | | | |
| | Soil Consistence | | | | | | |
| | Dry | - | 2 | - | 4 | - | - |
| | Moist | - | 2 | - | 4 | - | - |
| | Wet | | 2 | - | 4 - | - | - |
| Drainage | | | 6 | | | | |
| | Drainage Class | - | 3 | - | - | - | 0 |
| | Porosity | % | 2 | - | - | 2 | - |
| | Abundant/cm$^2$ | | | | | | |
| | Ground $H_2O$ table | cm | 3 | 9 | - | - | - |
| Avail. Water | | | 5 | | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Text. Class | - | 3 | - | 6 | - | - |
| Rooting Depth | | | 4 | | | | |
| Soil depth | cm | 3 | 9 | - | - | - | |
| Land Suitability | Sub -total | | | 24 | 14 | 3 | 0 |
| obtained Land Quality Index Grand Total | | | | | 41 | | |
| Ideal Index of soil condition for Maize production | | | | >80 | 40-80 | 20-40 | >20 |

S1 = High Suitability
S2 = Moderate or Medium Suitability
S3 = Low or Marginal Suitability
N1 = Very Low or not Suitable

## Land Suitability Classification of Soils in the Study Area for Maize Production

**Backswamp (EO4)**

| Land Quality | Land Characteristics | Unit | wt | High (S1) | Moderate (S2) | Low (S3) | Very Low (N1) |
|---|---|---|---|---|---|---|---|
| | | | | 3 | 2 | 1 | 0 |
| Land quality score | | | 4 | | | | |
| Fertility Status | Organic Carbon | % | 1 | - | - | 1 | - |
| | Ca | Cmol/kg | 1 | 3 | - | - | - |
| | Avail.P | µg/g | 1 | - | - | - | 0 |
| | Exch. K | Cmol/kg | 1 | - | - | - | 0 |
| | pH | - | 1 | 3 | - | - | - |
| | Base Saturation | % | 1 | 3 | - | - | - |
| Workability | | | 6 | | | | |
| | Soil Consistence | | | | | | |
| | Dry | - | 2 | - | 4 | - | - |
| | Moist | - | 2 | - | - | 2 | - |
| | Wet | | 2 | - | - | 2 | - |
| Drainage | | | 6 | | | | |
| | Drainage Class | - | 3 | - | - | - | 0 |
| | Porosity | % | 2 | - | - | 2 | - |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Abundant/cm$^2$ | | | | | | | |
| | Ground $H_2O$ table | cm | 3 | 9 | - | | - | - |
| Avail. Water | | | 5 | | | | | |
| | Text. Class | - | 3 | - | 6 | | - | - |
| Rooting Depth | | | 4 | | | | | |
| Soil depth | cm 3 9 | - | | - | - | | | |
| Land Suitability | Sub -total | | | 27 | 10 | | 7 | |
| obtained Land Quality Index Grand Total | | | | | 44 | | | |
| Ideal Index of soil condition for Maize production | | | | >80 | 40-80 | | 20-40 | >20 |

S1 = High Suitability
S2 = Moderate or Medium Suitability
S3 = Low or Marginal Suitability
N1 = Very Low or not Suitable

## Table 4.12 Land Suitability Classification of Soils in the Study Area for Sugarcane Production

**Levee Crest (EO1)**

| Land Quality | Land Characteristics | Unit | wt | High (S1) | Moderate (S2) | | Low (S3) | Very Low (N1) |
|---|---|---|---|---|---|---|---|---|
| | | | | 3 | 2 | | 1 | 0 |
| Land quality score | | | 4 | | | | | |
| | Organic Carbon | % | 1 | - | 2 | | - | - |
| | Total Nitrogen | % | 1 | - | 2 | | - | - |
| | Avail.P | m/kg | 1 | - | - | | 1 | - |
| | Exch. K | Cmol/kg | 1 | - | - | | - | 0 |
| | pH | - | 1 | - | 2 | | | |
| | Base Saturation | % | 1 | 3 | - | | - | - |
| Workability | | | 6 | | | | | |
| | Soil Consistence | | | | | | | |
| | Dry | - | 2 | - | 4 | - | - | - |
| | Moist | - | 2 | 6 | - | | - | - |
| | wet | | 2 | - | 4 | - | - | - |
| Drainage | | | 6 | | | | | |
| | Drainage Class | - | 3 | 9 | - | | - | - |

| Land Quality | Land Characteristics | Unit | wt | High (S1) | Moderate (S2) | Low (S3) | Very Low (N1) |
|---|---|---|---|---|---|---|---|
| | Porosity Abundant/cm$^2$ | % | 2 | - | - | 2 | - |
| | Ground $H_2O$ table | cm | 3 | 9 | - | - | - |
| | Annual Rainfall | mm | 2 | 6 | - | - | - |
| | Text. Class | - | 3 | - | 6 | - | - |
| Rooting Depth | | | 4 | | | | |
| | Soil depth | cm | 3 | 9 | - | - | - |
| | Land Suitability Subtotal | | | 42 | 20 | 3 | 0 |
| Obtained Land Quality Index Grand Total | | | | | 63 | | |
| Ideal Index of soil condition for Sugar Cane production | | | | >70 | 40-70 | 20-40 | >20 |

S1 = High Suitability
S2 = Moderate or Medium Suitability
S3 = Low or Marginal Suitability
N1 = Very Low or not Suitable

## Land Suitability Classification of Soils in the Study Area for Sugarcane Production

**Levee Slope (EO2)**

| Land Quality | Land Characteristics | Unit | wt | High (S1) 3 | Moderate (S2) 2 | Low (S3) 1 | Very Low (N1) 0 |
|---|---|---|---|---|---|---|---|
| Land quality score | | | 4 | | | | |
| Fertility Status | Organic Carbon | % | 1 | - | - | 1 | - |
| | Total Nitrogen | % | 1 | - | 2 | - | - |
| | Avail.P | m/kg | 1 | - | 2 | - | - |
| | Exch. K | Cmol/kg | 1 | - | - | - | 0 |
| | pH | - | 1 | - | 2 | - | - |
| | Base Saturation | % | 1 | 3 | - | - | - |
| Workability | | | 6 | | | | |
| | Soil Consistence | | | | | | |
| | Dry | - | 2 | - | 4 | - | - |
| | Moist | - | 2 | - | 4 | - | - |
| | Wet | | 2 | - | 4 | - | - |
| Drainage | | | 6 | | | | |
| | Drainage Class | - | 3 | 9 | - | - | - |
| | Porosity Abundant/cm$^2$ | % | 2 | - | - | 2 | - |

| Land Quality | Land Characteristics | Unit | wt | High (S1) | Moderate (S2) | | Low (S3) | Very Low (N1) |
|---|---|---|---|---|---|---|---|---|
| | Ground $H_2O$ table | cm | 3 | 9 | - | | - | - |
| | Annual Rainfall | mm | 2 | 6 | - | | - | - |
| | Text. Class | - | 3 | - | 6 | | - | - |
| | Rooting Depth | | 4 | | | | | |
| | Soil depth | cm | 3 | 9 | - | | - | - |
| | Land Suitability Subtotal | | 36 | 24 | | 3 | 0 | |
| obtained Land Quality Index Grand Total | | | | 63 | | | | |
| Ideal Index of soil condition for Sugar Cane production | | | >70 | 40-70 | | 20-40 | >20 | |

S1 = High Suitability
S2 = Moderate or Medium Suitability
S3 = Low or Marginal Suitability
N1 = Very Low or not Suitable

## Land Suitability Classification of Soils in the Study Area for Sugarcane Production

**Terrace (EO3)**

| Land Quality | Land Characteristics | Unit | wt | High (S1) | Moderate (S2) | Low (S3) | Very Low (N1) |
|---|---|---|---|---|---|---|---|
| | | | | 3 | 2 | 1 | 0 |
| Land quality score | | | 4 | | | | |
| Fertility Status | Organic Carbon | % | 1 | - | - | - | 0 |
| | Total Nitrogen | % | 1 | - | - | - | 0 |
| | Avail.P | m/kg | 1 | - | - | - | 0 |
| | Exch. K | Cmol/kg | 1 | - | - | - | 0 |
| | pH | - | 1 | - | 2 | - | - |
| | Base Saturation | % | 1 | 3 | - | - | - |
| Workability | | | 6 | | | | |
| | Soil Consistence | | | | | | |
| | Dry | - | 2 | - | 4 | - | - |
| | Moist | - | 2 | - | 4 | - | - |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Wet | | 2 | - | 4 | - | - |
| Drainage | | | 6 | | | | |
| | Drainage Class | - | 3 | - | - | - | 0 |
| | Porosity | % | 2 | - | - | 2 | - |
| | Abundant/cm$^2$ | | | | | | |
| | Ground $H_2O$ table | cm | 3 | 9 | - | - | - |
| | Annual Rainfall | mm | 2 | 9 | - | - | - |
| | Text. Class | | 3 | - | 6 | - | - |
| Rooting Depth | | | 4 | | | | |
| | Soil depth | cm | 3 | 9 | - | - | - |
| | Land Suitability Subtotal | | 30 | 20 | 2 | 0 | - |
| obtained Land Quality Index Grand Total | | | | | 52 | | |
| Ideal Index of soil condition for Sugar Cane production | | | | >70 | 40-70 | 20-40 | >20 |

S1 = High Suitability
S2 = Moderate or Medium Suitability
S3 = Low or Marginal Suitability
N1 = Very Low or not Suitable

## Land Suitability Classification of Soils in the Study Area for Sugarcane Production

**Backswamp (EO4)**

| Land Quality | Land Characteristics | Unit | wt | High (S1) | Moderate (S2) | Low (S3) | Very Low (N1) |
|---|---|---|---|---|---|---|---|
| | | | | 3 | 2 | 1 | 0 |
| Land quality score | | | 4 | | | | |
| Fertility Status | Organic Carbon | % | 1 | - | 2 | - | - |
| | Total Nitrogen | % | 1 | - | - | 3 | - |
| | Avail.P | m/kg | 1 | - | 2 | - | - |
| | Exch. K | Cmol/kg | 1 | - | - | - | 0 |
| | pH | - | 1 | 3 | - | | |
| | Base Saturation | % | 1 | 3 | - | - | - |
| Workability | | | 6 | | | | |
| | Soil Consistence | | | | | | |
| | Dry | - | 2 | - | 4 | - | - |
| | Moist | - | 2 | - | - | 2 | - |
| | Wet | | 2 | - | - | 2 | - |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Drainage | | | 6 | | | | |
| | Drainage Class | - | 3 | - | - | - | 0 |
| | Porosity | % | 2 | - | - | 2 | - |
| | Abundant/cm$^2$ | | | | | | |
| | Ground $H_2O$ table | cm | 3 | 9 | - | - | - |
| | Annual Rainfall | mm | 2 | 9 | - | - | - |
| | Text. Class | - | 3 | - | 6 | - | - |
| Rooting Depth | | | 4 | | | | |
| | Soil depth | cm | 3 | 9 | - | - | - |
| | Land Suitability Subtotal | | | 33 | 14 | 9 | 0 |
| obtained Land Quality Index Grand Total | | | | | 56 | | |
| Ideal Index of soil condition for Sugar Cane production | | | | >70 | 40-70 | 20-40 | >20 |

S1 = High Suitability
S2 = Moderate or Medium Suitability
S3 = Low or Marginal Suitability
N1 = Very Low or not Suitable

### 4.5.5 Relationship among the Surface Soil Studied

A correlation matrix of relationships between surface soil properties in the study area is shown in (Table 4.13a). The result of the rank correlation among the surface soil propertiesshowed that correlation co-efficient of sand wasnegative but statistically significant ($P < 0.01$) with clay content. %Base saturation had a negative correlation with total exchangeable acid ($P<0.05$) and a high positive correlation with total exchangeable base, ($P<0.01$). Aluminum saturation had positive correlation with Al and H ($P<0.05$), C/N had a negative correlation with K ($P<0.05$) and a positive correlation with Mg ($P<0.05$), Ca/Mg had a negative correlation with nitrogen, total exchangeable base, ($P<0.05$) and a high negative correlation with Mg ($P<0.01$), Cation exchange capacity had a high negative correlation with ESP ($P<0.01$), a positive correlation with N ($P<0.05$), a high positive correlation with total exchangeable bases and Mg ($P<0.01$), ESP had a high positive correlation with sodium ($P<0.01$), high negative correlation with magnesium P<(0.01), a high positive correlation Al, H, and TN ($P<0.01$). Total nitrogen had a positive correlation with total exchangeable base, and magnesium ($P<0.05$) in the studied area.

## Table 4.13a: Relationship among the Properties of the Surface Soil Studied

| | Sand | clay | %BS | Al. Sat | CEC | C/N | Ca/Mg | ECEC | ESP | TE A | Al | H | TN | Na | OC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Silt | | | | | | | | | | | | | | | |
| Clay | -0.974** | 1 | | | | | | | | | | | | | |
| %BS | -0.016ns | -0.034 ns | 1 | | | | | | | | | | | | |
| AlSat | 0.334 ns | -0.307 ns | -0.254 ns | 1 | | | | | | | | | | | |
| CEC | 0.331 ns | -0.371 ns | 0.212 ns | -0.184 ns | 1 | | | | | | | | | | |
| C/N | -0.007 ns | -0.027 ns | 0.006 ns | -0.117 ns | 0.362 ns | 1 | | | | | | | | | |
| Ca/Mg | 0.351 ns | -0.349 ns | -0.277 ns | 0.048 ns | 0.020 ns | -0.089 ns | 1 | | | | | | | | |
| ECEC | 0.021 ns | -0.034 ns | -0.137 ns | 0.157 ns | 0.137 ns | 0.296 ns | -0.479 ns | 1 | | | | | | | |
| ESP | 0.227 ns | -0.228 ns | -0.035 ns | 0.300 ns | -0.257 ns | -0.368 ns | 0.475 ns | -0.611** | 1 | | | | | | |
| TEA | 0.145 ns | -0.077 ns | -0.484* | 0.360 ns | -0.340 ns | 0.053 ns | 0.111 ns | 0.421 ns | 0.117 ns | 1 | | | | | |
| Al | 0.466 ns | -0.393 ns | -0.028 ns | 0.497* | -0.070 ns | -0.391 ns | -0.219 ns | 0.445 ns | 0.079 ns | 0.382 ns | 1 | | | | |
| H | 0.404 ns | -0.442 ns | -0.003 ns | 0.481* | -0.124 ns | -0.406 ns | 0.040 ns | 0.262 ns | 0.336 ns | 0.276 ns | 0.756** | 1 | | | |
| N | -0.129 ns | 0.150 ns | 0.173 ns | -0.062 ns | 0.174 ns | -0.013 ns | -0.505* | 0.546* | -0.193 ns | 0.256 ns | 0.447 ns | 0.311 ns | 1 | | |
| Na | 0.263 ns | -0.271 ns | -0.038 ns | 0.204 ns | -0.100 ns | -0.187 ns | 0.028 ns | 0.095 ns | 0.659** | 0.393 ns | 0.473 ns | 0.620** | 0.381 ns | 1 | |
| OC | 0.024 ns | -0.023 ns | -0.107 ns | -0.096 ns | 0.390 ns | 0.175 ns | 0.150 ns | 0.203 ns | 0.132 ns | 0.397 ns | 0.129 ns | 0.11 ns 3 | 0.619** | 0.400 ns | 1 |
| P | 0.116 ns | -0.157 ns | 0.454 ns | -0.264 ns | 0.106 ns | 0.266 ns | 0.282 ns | -0.056 ns | -0.040 ns | 0.094 ns | -0.168 ns | -0.174 ns | -0.271 ns | -0.109 ns | 0.013 ns |
| TEB | 0.026 ns | -0.073 ns | 0.700** | -0.097 ns | 0.272 ns | 0.212 ns | -0.530* | 0.610** | -0.465 ns | -0.075 ns | 0.303 ns | 0.190 ns | 0.521* | 0.038 ns | 0.074 ns |
| ca | 0.106 ns | -0.148 ns | -0.151 ns | 0.084 ns | 0.050 ns | -0.115 ns | 0.122 ns | 0.379 ns | -0.291 ns | -0.169 ns | 0.101 ns | 0.223 ns | -0.182 ns | -0.095 ns | -0.275 ns |
| k | -0.427 ns | 0.423 ns | -0.170 ns | 0.019 ns | -0.416 ns | -0.563* | -0.206 ns | -0.216 ns | 0.161 ns | -0.258 ns | 0.071 ns | 0.194 ns | 0.236 ns | 0.056 ns | -0.110 ns |
| mg | -0.138 ns | 0.110 ns | 0.333 ns | -0.147 ns | 0.413 ns | 0.486* | -0.729** | 0.602** | -0.610** | -0.050 ns | 0.154 ns | -0.108 ns | 0.582* | -0.126 ns | 0.192 ns |

Where: *= significant at 0.05 probability level, **= significant at 0.01 probability level, and ns=not significant

### 4.5.6 Relationships among the Physico-Chemical Properties of the Studied Pedons

A correlation matrix showing relationships between soil properties of the pedons in the study area is shown in (Table 4.13b). The results of the rank correlation among the soil propertiesshowed that correlation between sand and clay, Ca/mgwasnegative but statistically significant(P<0.01). Clay recorded high negative correlation with bulk density (P<0.01), a high positive correlation with Total porosity, Organic carbon, and a high negative correlation with pH ($H_2O$) (P<0.01). Bulk density had a positive correlation with pH ($H_2O$), and a high negative correlation with organic carbon and P (P<0.01). Total porosity had a high negative correlation with pH ($H_2O$) and a high positive correlation with nitrogen, organic carbon, and phosphorous (P<0.01). %Base saturation had a high negative correlation with total exchangeable acid, aluminum saturation, $Al^+$, and $H^+$ (P<0.01). Aluminum saturation had high positive correlation with total exchangeable acid, $Al^+$ and $H^+$ (P<0.01). pH ($H_2O$) had a negative correlation with nitrogen, and organic carbon (P<0.05). Cation exchange capacity had a positive correlation with ECEC (P<0.05) and a high positive correlation with total exchangeable base (P<0.01).

# Table 4.13b: Relationships among the Physico-Chemical Properties of the Studied Pedons

| | Sand | Clay | BD | TP | MC | %BS | Al Sat | Ph(H20) | CEC | C/N | Ca/Mg | ECEC | ESP | TEA | N | Na | OC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Sand** | 1 | | | | | | | | | | | | | | | | |
| **CLAY** | -0.608** | 1 | | | | | | | | | | | | | | | |
| **BDg** | 0.182ns | -0.689** | 1 | | | | | | | | | | | | | | |
| **TP** | -0.193 ns | 0.696** | -0.100 ns | 1 | | | | | | | | | | | | | |
| **MC** | -0.108 ns | 0.314 ns | -0.056 ns | 0.058 ns | 1 | | | | | | | | | | | | |
| **%BS** | -0.057 ns | 0.259 ns | -0.035 ns | 0.040 ns | 0.062 ns | 1 | | | | | | | | | | | |
| **AlSat** | -0.189 ns | -0.009 ns | -0.004 ns | 0.007 ns | -0.128 ns | -0.819** | 1 | | | | | | | | | | |
| **Ph(H20)** | 0.245 ns | -0.647** | 0.676** | -0.685** | -0.149 ns | -0.042 ns | -0.171 ns | 1 | | | | | | | | | |
| **CEC** | 0.014 ns | -0.097 ns | -0.192 ns | 0.181 ns | -0.059 ns | 0.200 ns | -0.480 ns | 0.378 ns | 1 | | | | | | | | |
| **C/N** | 0.455 ns | 0.197 ns | -0.077 ns | 0.073 ns | 0.191 ns | 0.433 ns | -0.382 ns | -0.069 ns | -0.222 ns | 1 | | | | | | | |
| **Ca/Mg** | -0.691** | 0.259 ns | 0.095 ns | -0.087 ns | 0.122 ns | -0.235 ns | 0.452 ns | 0.050 ns | 0.105 ns | -0.549* | 1 | | | | | | |
| **ECEC** | 0.412 ns | -0.149 ns | -0.358 ns | 0.344 ns | -0.071 ns | -0.313 ns | 0.151 ns | 0.036 ns | 0.511* | -0.066 ns | -0.246 ns | 1 | | | | | |
| **ESP** | -0.161 ns | 0.006 ns | 0.169 ns | -0.165 ns | 0.298 ns | 0.411 ns | -0.338 ns | -0.146 ns | -0.042 ns | -0.266 ns | -0.012 ns | -0.365 ns | 1 | | | | |
| **TEA** | -0.218 ns | 0.017 ns | -0.110 ns | 0.111 ns | -0.042 ns | -0.886** | 0.914** | -0.162 ns | -0.310 ns | -0.471 ns | 0.427 ns | 0.278 ns | -0.374 ns | 1 | | | |
| **Al** | -0.145 ns | -0.032 ns | -0.071 ns | 0.073 ns | -0.090 ns | -0.824** | 0.971** | -0.164 ns | -0.377 ns | -0.433 ns | 0.420 ns | 0.301 ns | -0.322 ns | 0.940** | | | |
| **H** | -0.145 ns | -0.032 ns | -0.072 ns | 0.073 ns | -0.090 ns | -0.824** | 0.971** | -0.164 ns | -0.377 ns | -0.433 ns | 0.420 ns | 0.301 ns | -0.322 ns | 0.940** | | | |
| **N** | -0.466 ns | 0.340 ns | -0.479 ns | 0.481* | -0.033 ns | -0.118 ns | 0.118 ns | -0.532* | 0.092 ns | -0.514* | 0.167 ns | -0.074 ns | 0.192 ns | 0.170 ns | 1 | | |
| **Na** | -0.219 ns | 0.072 ns | 0.039 ns | -0.039 ns | 0.313 ns | -0.279 ns | 0.386 ns | 0.027 ns | -0.029 ns | -0.192 ns | 0.382 ns | 0.228 ns | -0.051 ns | 0.330 ns | -0.017 ns | 1 | |
| **OC** | -0.115 ns | 0.716** | -0.753** | 0.754** | 0.233 ns | 0.357 ns | -0.372 ns | -0.556* | 0.067 ns | 0.368 ns | -0.290 ns | -0.063 ns | 0.029 ns | -0.278 ns | 0.387 ns | -0.173 ns | 1 |
| **P** | -0.187 ns | 0.366 ns | -0.640** | 0.634** | 0.268 ns | -0.199 ns | 0.002 ns | -0.277 ns | 0.347 ns | -0.203 ns | -0.023 ns | 0.192 ns | 0.066 ns | 0.106 ns | 0.643** | 0.059 ns | 0.550* |
| **TEB** | 0.369 ns | 0.041 ns | -0.398 ns | 0.387 ns | -0.043 ns | 0.335 ns | -0.355 ns | -0.025 ns | 0.614** | 0.233 ns | -0.138 ns | 0.788** | -0.119 ns | -0.293 ns | -0.146 ns | 0.042 ns | 0.174 ns |
| **Ca** | -0.472 ns | 0.375 ns | -0.232 ns | 0.232 ns | 0.278 ns | 0.128 ns | -0.058 ns | -0.019 ns | 0.555* | -0.328 ns | 0.703** | 0.391 ns | 0.039 ns | 0.049 ns | 0.117 ns | 0.384 ns | 0.022 ns |
| **K** | -0.289 ns | 0.412 ns | -0.331 ns | 0.329 ns | -0.085 ns | 0.292 ns | -0.247 ns | -0.178 ns | 0.206 ns | 0.200 ns | 0.082 ns | 0.085 ns | -0.205 ns | -0.097 ns | 0.078 ns | -0.237 ns | 0.320 ns |
| **mg** | 0.780** | -0.281 ns | -0.296 ns | 0.283 ns | -0.172 ns | 0.144 ns | -0.370 ns | 0.020 ns | 0.404 ns | 0.416 ns | -0.658** | 0.681** | -0.243 ns | -0.282 ns | -0.216 ns | -0.251 ns | 0.173 ns |

**Where: *= significant at 0.05 probability level, **= significant at 0.01 probability level, ns= not significant**

C/N had a negative correlation with Ca/Mg and nitrogen ($P<0.05$). ECEC had a high positive correlation with TEB ($P<0.01$). Total exchangeable acid had a high positive correlation with $Al^{+}$ and $H^{+}$ ($P<0.01$). Nitrogen had a high positive correlation with p (0.01). Organic carbon had a positive correlation with phosphorous ($P<0.05$) in the studied area.

### 4.5.7 Variability among Physical Properties of Soil in the Studied Area

In this study, the variability of Bulk density as shown in Table (4.14a) was low in the soils of the levee crest (EO1) and levee slope (EO2). Similar results were obtained by Haile *et al* (2014) for a Eutric cambisol and medium variability in the soils of terrace (EO3) and backswamp (EO4). Percent Moisture content was highly varied in among the soils of the levee crest, low in variability among the soils of the levee slope, medium among the soils of the terrace and low among the soils of the backswamp. A low variability in Total porosity and Sand was observed, in the soils of the four geomorphic units. This was in agreement with the results of Martins *et al* (2012) in a Eutric cambisol. Clay content was highly varied in the soils of the levee crest, medium at levee slope, high at terrace and medium in the soils of the backswamp.

**Table 4.14a Variability among the Soil Physical Properties of theStudy Area**

| BD | MC | TP | SAND | SILT | CLAY |
|---|---|---|---|---|---|
| 5.8 | 140.2 | 5 | 2.1 | 0 | 30.4 |
| Low | high | low | low | 0 | high |
| 12.9 | 14.7 | 10.5 | 1.9 | 0 | 29.8 |
| Low | low | low | low | 0 | medium |
| 16.7 | 15.1 | 13.3 | 5 | 0 | 63.2 |
| Medium | medium | low | low | 0 | high |
| 15.6 | 15 | 13.3 | 1.3 | 0 | 29.4 |
| Medium | low | low | low | 0 | medium |

### 4.5.8 Variability among Chemical Properties of the Soils in the Study Area

From Table 4.14b, the CV of the pH values was low (3.3%, pH ($H_2O$), and 3.6% pH KCl), similarly Hudec (2013), observed a low CV for pH in Cambisols. A low CV was expected for pH because values typically varied over a narrow interval. Moreover the CV of pH cannot be compared with other properties because it is measured on a logarithmic scale. Sodium showed high variability on the soils of the levee crest and low variability in the soils of the levee slope, terrace, and backswamp. A low variability of %Base saturation was observed in the soils of the four geomorphic units. Nitrogen content was highly variable in the soils of the levee crest, levee slope, and terrace, while low variability was observed in the soils of the backswamp. Organic carbon showed high variability in the soils of the levee crest, levee slope, terrace, and medium variability in the soils of the backswamp. A high variability of Organic matter content was observed in the soils of the four geomorphic surfaces. The C/N ratio showed medium variability in soils of levee crest, high variability in soils of levee slope, low variability in terrace and medium variability in soils of backswamp.

## Table 4.14b: Variability of Soil Chemical Properties of the Studied Geomorphic Units

| Soil Property | pH $H_2O$ | pH KCL | N | OC % | OM | C/N ratio | P (m/kg) | Ca/Mg % | Ca | Mg | $K^+$ | $Na^+$ | $Al^+$ Cmol/kg | $H^+$ | TEA | CEC | ECEC | TEB | %BS % | ESP | Al.Sat |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Levee crest EO1 | | | | | | | | | | | | | | | | | | | | | |
| **CV(%)** | 3.3 | 3.6 | 43.4 | 39.1 | 39.2 | 16.4 | 121.5 | 33.6 | 27.9 | 20.9 | 52.9 | 60.5 | 74.2 | 38.1 | 74.2 | 26.5 | 11.2 | 21.1 | 14.2 | 33.9 | 46.2 |
| **Rank** | low | low | high | High | high | medium | high | medium | medium | medium | high | high | high | high | high | medium | low | medium | low | medium | high |
| **Levee Slope EO2** | | | | | | | | | | | | | | | | | | | | | |
| **CV(%)** | 7 | 7.2 | 86.7 | 123.2 | 118 | 67.3 | 92.2 | 32.9 | 11.7 | 31.7 | 28.3 | 13.3 | 19.6 | 19.6 | 19.6 | 2.6 | 9 | 12.9 | 6.2 | 21 | 20.7 |
| **Rank** | low | low | high | High | high | high | high | medium | low | medium | medium | low | medium | medium | medium | low | low | low | low | medium | medium |
| **Terrace EO3** | | | | | | | | | | | | | | | | | | | | | |
| **CV(%)** | 4 | 4.8 | 77.3 | 57.5 | 57.5 | 14 | 78.4 | 14 | 16.6 | 23.6 | 43 | 5.5 | 30.7 | 30.7 | 30.6 | 18 | 12.8 | 6.5 | 9 | 11.4 | 27.4 |
| **Rank** | low | low | high | High | high | low | high | low | medium | medium | high | low | medium | medium | medium | medium | low | low | low | low | low |
| **Backswamp EO4** | | | | | | | | | | | | | | | | | | | | | |
| **CV(%)** | 1.7 | 1.6 | 6.4 | 15.5 | 75.4 | 19.3 | 64.6 | 69.5 | 28.4 | 22.5 | 24.5 | 7.5 | 33.3 | 33.3 | 33.2 | 23.5 | 20.5 | 22.1 | 2 | 27.9 | 16.7 |
| **Rank** | low | low | low | medium | high | medium | high | high | medium | medium | medium | [ow | medium | medium | medium | medium | medium | medium | low | medium | medium |

Phosphorous showed high variability in soils the soils of the four geomorphic surfaces. The Ca/Mg ratio showed medium variability in soils of the levee slope and levee crest, low variability in soils of the terrace and high variability in soils of the backswamp. Calcium showed medium variability in soils of the levee crest, low variability in soils of the levee slope while the soils of terrace and backswamp showed medium variability. Magnesium showed medium variability in all the soils of the four geomorphic units. Potassium showed high variability in the soils of the levee crest, medium variability in the soils of the levee slope, high variability in the soils of the soils of the terrace and medium variability in the soils of the backswamp. Percent Aluminum showed high variability in the soils of the levee crest, while soils of the levee slope, terrace and backswamp showed medium variability. % Hydrogen showed low variability in the soils of the levee crest and levee slope, however soils of the terrace and backswamp showed medium variability. TEA showed high variability in the soils of the levee crest while the soils of the levee slope, terrace and backswamp showed medium variability. CEC showed medium variability in the soils of the levee crest, low variability in levee slope, and medium variability in soils of the terrace and backswamp. ECEC showed low variability in the soils of the levee crest, levee slope, and terrace while the soils of the backswamp showed medium variability. TEB showed medium variability in the soils of the levee crest, low variability in the soils of the slope and terrace while soils of the backswamp showed medium variability. ESP showed medium variability in the soils of the levee crest and levee slope, low variability in the soils of the terrace while the soils of the backswamp showed medium variability. Aluminum saturation showed high variability in the soils of the levee crest, medium variability in the soils of the levee slope, low in the soils of the terrace while the soils of the backswamp showed medium variability.

Table 4.15a: shows the least significant difference in physical properties of the surface soil studied.

## TABLE 4.15a: PHYSICAL PROPERTIES OF THE SURFACE SOIL STUDIED

| Dept(cm) | TP | BD(mg/m3) | MC% | Sand(g/kg) | Silt(g/kg) | Clay(g/kg) | Texture |
|---|---|---|---|---|---|---|---|
| | **Levee crest** | | | | | | |
| 0-20 | 1.08 | 8.10 | 41.19 | 856.0 | 16.0 | 128.0 | Sand |
| 0-20 | 1.07 | 8.25 | 40.80 | 876.0 | 16.0 | 108.0 | Sand |
| 0-20 | 1.10 | 7.89 | 41.97 | 856.0 | 16.0 | 128.0 | Sand |
| 0-20 | 1.12 | 8.56 | 42.75 | 896. | 16.0 | 88.0 | Sand |
| **Mean** | **1.09** | **8.20** | **41.68** | **871.** | **16.0** | **113.0** | |
| | **Levee Slope** | | | | | | |
| 0-20 | 0.74 | 6.97 | 27.91 | 896.0 | 16.0 | 88.0 | Sand |
| 0-20 | 1.12 | 8.90 | 42.75 | 896.0 | 16.0 | 88.0 | Sand |
| 0-20 | 1.16 | 8.99 | 44.31 | 896.0 | 16.0 | 88.0 | Sand |
| 0-20 | 0.94 | 7.28 | 45.88 | 896.0 | 16. | 88.0 | Sand |
| **Mean** | **1.02** | **8.02** | **40.21** | **896.0** | **16.0** | **88.0** | |
| | **Terrace** | | | | | | |
| 0-20 | 0.62 | 8.00 | 23.22 | 936.0 | 16.0 | 48.0 | Sand |
| 0-20 | 1.14 | 8.20 | 43.53 | 916.0 | 16.0 | 68.0 | Sand |
| 0-20 | 1.18 | 11.10 | 45.09 | 896.0 | 16.0 | 88.0 | Sand |
| 0-20 | 0.82 | 10.78 | 31.03 | 896.0 | 16.0 | 88.0 | Sand |
| **Mean** | **0.94** | **9.52** | **35.72** | **911.0** | **16.0** | **73.0** | |
| | **Backswamp** | | | | | | |
| 0-20 | 0.90 | 21.84 | 34.16 | 876.0 | 16.0 | 108.0 | L Sand |
| 0-20 | 1.25 | 22.80 | 47.83 | 836.0 | 16.0 | 148.0 | L Sand |
| 0-20 | 1.22 | 28.78 | 46.66 | 876.0 | 16.0 | 128.0 | L Sand |
| 0-20 | 1.00 | 21.91 | 38.06 | 866.0 | 16.0 | 108.0 | L Sand |
| **Mean** | **1.09** | **23.83** | **41.68** | **861.0** | **16.0** | **123.0** | |
| **LSD(0.05)** | **1.562** | **2.873** | **4.341** | **289.9** | **NS** | **273.2** | |

**Table 4.15b: Physical Characteristic of Soils of the Study Area (Pedon)**

| Horizon | Dept(cm) | BD(mg/m) | MC (%) | TP (%) | Sand(g/k) | Silt(g/kg) | Clay(g/kg) | Texture |
|---|---|---|---|---|---|---|---|---|
| | | | | **Levee Crest Soils (EO1)** | | | | |
| A | 0-20 | 1.12 | 8.56 | 57.74 | 896.0 | 16.0 | 88.0 | Sand |
| Ab | 20-65 | 1.24 | 8.92 | 53.21 | 916.0 | 16.0 | 68.0 | Sand |
| BG1 | 65-120 | 1.27 | 8.01 | 52.08 | 936.0 | 16.0 | 48.0 | Sand |
| Bt2 | 120-200 | 1.27 | 7.79 | 52.08 | 936.0 | 16.0 | 48.0 | Sand |
| | **Mean** | **1.23** | **8.32** | **53.32** | **922.1** | **16.0** | **63.0** | |
| | | | | **Levee Slope** | | | | |
| A | 0-21 | 0.94 | 7.2 | 64.53 | 896.0 | 16.0 | 88.0 | Sand |
| Ab | 21-35 | 1.16 | 8.91 | 56.23 | 896.0 | 16.0 | 68.0 | Sand |
| BG1 | 35-65 | 1.25 | 9.2 | 52.83 | 856.6 | 16.0 | 48.0 | L Sand |
| BG2 | 65-108 | 1.29 | 9.56 | 51.32 | 876.0 | 16.0 | 48.0 | L Sand |
| BG3 | 108-200 | 1.32 | 10.96 | 50.19 | 876.0 | 16.0 | 48.0 | L Sand |
| | **Mean** | **1.19** | **9.23** | **55.02** | **880.0** | **16.0** | **60.0** | |
| | | | | **Terrace** | | | | |
| A | 0-5 | 0.82 | 8.05 | 69.06 | 896.0 | 16.0 | 88.0 | Sand |
| Ab | 5-34 | 1.22 | 8.55 | 53.96 | 856.0 | 16.0 | 88.0 | Sand |
| BA | 34-56 | 1.23 | 11.43 | 53.58 | 956.0 | 16.0 | 28.0 | Sand |
| BG1 | 56-98 | 1.24 | 10.98 | 53.21 | 956.0 | 16.0 | 28.0 | Sand |
| BG2 | 98-200 | 1.3 | 10.3 | 50.24 | 956.0 | 16.0 | 28.0 | Sand |
| | **Mean** | **1.16** | **9.86** | **56.15** | **931.8** | **16.0** | **52.0** | |
| | | | | **Backswamp** | | | | |
| A | 0-4 | 1 | 21.91 | 62.26 | 876.0 | 16.0 | 88.0 | L Sand |
| Ab | 4-84 | 1.32 | 23.2 | 50.19 | 896.0 | 16.0 | 68.0 | Sand |
| BG1 | 84-100 | 1.34 | 28.84 | 49.43 | 896.0 | 16.0 | 48.0 | Sand |
| | **Mean** | **1.22** | **24.65** | **53.96** | **889.3** | **16.0** | **63.0** | |

## Table 4.16a Chemical Characteristics of the Surface Samples in the Study Area

| | ← % → | | | | | | → Exchangeable Cations Cmol/Kg ← | | | | | | | | → % ← | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Replicates | Soil pH in $H_2O$ 1:2.5 | Soil pH in KCL 1:1 | Tot N % | Org Carbon | C/NRatio | Ca/Mg Ratio | Avail P µg/g | $Ca^{2+}$ | $Mg^{2+}$ | K | $Na^{2+}$ | Exch. $Al^{+}$cmol/kg | Exch. $H^{+}$ Cmol/kg | TEA | ECEC | TEB % | Bs % | Esp 5 | Al Sat. (%) |
| | | | | | | | | **Levee Crest Soils (Typic Eutrudepts)** | | | | | | | | | | | |
| | 6.00 | 3.90 | 0.047 | 0.56 | 1.19 | 0.28 | 0.46 | 1.97 | 0.70 | 0.26 | 0.10 | 0.19 | 0.57 | 0.76 | 3.79 | 3.03 | 79.95 | 2.64 | 5.01 |
| | 6.38 | 3.71 | 0.108 | 0.82 | 7.59 | 11.11 | 0.29 | 1.78 | 1.60 | 0.21 | 0.11 | 0.22 | 0.94 | 1.16 | 4.86 | 3.70 | 76.13 | 2.26 | 4.53 |
| | 6.49 | 5.19 | 0.073 | 0.68 | 9.32 | 2.51 | 0.88 | 3.26 | 1.30 | 0.13 | 0.09 | 0.15 | 0.45 | 0.06 | 5.38 | 4.78 | 88.85 | 1.67 | 2.79 |
| | 5.99 | 4.03 | 0.035 | 0.50 | 14.29 | 1.44 | 1.38 | 1.44 | 1.50 | 0.06 | 0.12 | 0.22 | 0.66 | 0.88 | 4.72 | 3.84 | 81.36 | 2.54 | 4.66 |
| **Mean** | **6.21** | **4.21** | **0.066** | **0.64** | **8.10** | **1.34** | **0.67** | **2.29** | **1.28** | **0.17** | **0.11** | **0.20** | **0.66** | **0.85** | **4.69** | **3.84** | **81.57** | **2.28** | **4.25** |
| | | | | | | | | **Levee Slope Soils (Typic Hapludults)** | | | | | | | | | | | |
| | 5.93 | 3.89 | 0.056 | 0.62 | 11.07 | 1.37 | 0.43 | 2.06 | 1.50 | 0.13 | 0.10 | 0.27 | 0.81 | 1.08 | 4.87 | 3.70 | 77.82 | 2.55 | 2.18 |
| | 5.93 | 3.91 | 0.050 | 0.50 | 0.10 | 1.70 | 0.69 | 2.26 | 1.30 | 0.17 | 0.10 | 0.28 | 0.84 | 0.12 | 3.95 | 3.83 | 96.96 | 2.53 | 7.09 |
| | 5.92 | 3.94 | 0.102 | 0.80 | 7.84 | 1.29 | 0.31 | 2.20 | 1.70 | 0.26 | 0.11 | 0.31 | 0.93 | 0.24 | 4.51 | 4.27 | 94.68 | 2.43 | 6.87 |
| | 6.11 | 3.85 | 0.092 | 0.83 | 9.02 | 0.86 | 2.13 | 2.06 | 1.80 | 0.06 | 0.11 | 0.25 | 0.75 | 0.76 | 4.27 | 5.51 | 129.03 | 2.58 | 4.45 |
| **Mean** | **5.97** | **3.90** | **0.075** | **0.69** | **7.01** | **1.31** | **0.89** | **2.21** | **1.20** | **0.16** | **0.11** | **0.28** | **0.83** | **1.55** | **4.40** | **3.85** | **99.61** | **2.53** | **10.15** |
| | | | | | | | | **Terrace (Typic Hapludult)** | | | | | | | | | | | |
| | 6.16 | 4.05 | 0.063 | 0.66 | 10.48 | 1.44 | 0.40 | 2.16 | 1.50 | 0.10 | 0.10 | 0.18 | 0.36 | 0.48 | 4.40 | 3.92 | 89.09 | 2.27 | 4.09 |
| | 5.65 | 3.94 | 0.110 | 0.86 | 7.82 | 21.1 | 1.45 | 2.11 | 0.10 | 0.10 | 0.10 | 0.12 | 0.60 | 0.80 | 3.21 | 2.41 | 75.08 | 3.12 | 6.23 |
| | 6.05 | 4.04 | 0.043 | 0.42 | 9.77 | 2.27 | 1.24 | 2.50 | 1.10 | 0.17 | 0.09 | 0.20 | 0.87 | 0.16 | 4.02 | 3.86 | 96.02 | 2.24 | 7.21 |
| | 5.86 | 3.91 | 0.074 | 0.76 | 10.27 | 0.94 | 1.24 | 2.06 | 2.20 | 0.10 | 0.08 | 0.29 | 0.63 | 0.84 | 5.28 | 4.44 | 84.09 | 1.52 | 3.98 |
| **Mean** | **5.85** | **3.99** | **0.073** | **0.68** | **9.58** | **6.44** | **0.82** | **2.21** | **1.23** | **0.09** | **0.09** | **0.21** | **0.62** | **0.57** | **4.23** | **3.66** | **86.06** | **2.29** | **5.38** |
| | | | | | | | | **Backswamp Soils (Typic Endoaquept)** | | | | | | | | | | | |
| | 5.91 | 3.91 | 0.114 | 1.40 | 12.28 | 0.99 | 0.34 | 1.78 | 1.80 | 0.13 | 0.12 | 0.22 | 0.66 | 0.88 | 4.71 | 3.83 | 81.32 | 2.54 | 4.67 |
| | 6.10 | 3.93 | 0.056 | 1.59 | 10.54 | 0.95 | 0.56 | 1.52 | 1.60 | 0.21 | 0.09 | 0.02 | 0.06 | 0.08 | 3.50 | 3.42 | 97.71 | 2.57 | 0.57 |
| | 6.37 | 4.52 | 0.064 | 1.67 | 10.47 | 1.09 | 0.68 | 1.63 | 1.50 | 0.13 | 0.08 | 0.20 | 0.06 | 0.08 | 4.14 | 3.34 | 80.68 | 1.93 | 4.83 |
| | 6.47 | 4.35 | 0.037 | 1.63 | 17.03 | 0.96 | 1.48 | 1.92 | 2.00 | 0.10 | 0.07 | 0.03 | 0.09 | 0.12 | 4.21 | 4.09 | 97.15 | 1.66 | 0.71 |
| | **Mean** | **6.21** | **4.23** | **0.82** | **1.27** | **12.58** | **1.00** | **0.77** | **1.71** | **1.73** | **0.14** | **0.09** | **0.12** | | | | | | |

# TABLE 4.16b: Chemical Properties of the Studied Geomorphic Units Pedons

| Horizon | Dept(cm) | pH (H2O) | pH (KCL) | N(%) | OC(%) | OM | C/N ratio | P(PPM) | Ca/Mg % | ca | mg | k | Na | Al | H | TE A | CEC | ECEC | TEB | %BS | ESP(%) | Al.Sat(% |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | Cmolkg$^{-1}$ | | | | | | | | | | | | |
| **EO1 Levee Crest (pedon)** | | | | | | | | | | | | | | | | | | | | | | |
| **A** | 0-20 | 5.99 | 4.03 | 0.035 | 0.50 | 0.86 | 14.29 | 1.38 | 1.44 | 2.16 | 1.50 | 0.06 | 0.12 | 0.22 | 0.66 | 0.88 | 2.00 | 4.72 | 3.84 | 81.36 | 2.48 | 4.66 |
| **AB** | 20-65 | 6.31 | 4.14 | 0.020 | 0.38 | 0.66 | 19.00 | 0.40 | 0.85 | 1.10 | 1.30 | 0.06 | 0.09 | 0.27 | 0.81 | 1.08 | 1.06 | 3.63 | 2.55 | 70.25 | 1.04 | 7.44 |
| **Bg$_1$** | 65-120 | 6.4 | 4.27 | 0.017 | 0.24 | 0.41 | 13.12 | 0.11 | 0.72 | 1.44 | 2,00 | 0.06 | 0.01 | 0.11 | 0.33 | 0.44 | 1.98 | 4.04 | 3.60 | 89.11 | 2.48 | 2.72 |
| **Bg$_2$** | 120-200 | 6.52 | 4.37 | 0.014 | 0.22 | 0.38 | 15.71 | 0.10 | 0.84 | 1.68 | 2.00 | 0.01 | 0.11 | 0.15 | 0.45 | 0.06 | 2.00 | 4.40 | 4.34 | 98.64 | 2.45 | 3.34 |
| | **Mean** | **6.31** | **4.20** | **0.022** | **0.34** | **0.58** | **15.55** | **0.50** | **0.96** | **1.60** | **1.70** | **0.05** | **0.11** | **0.19** | **0.56** | **0.75** | **1.76** | **4.20** | **7.33** | **84.84** | **2.11** | **4.54** |
| **Levee Slope EO2** | | | | | | | | | | | | | | | | | | | | | | |
| **A** | 0-21 | 6.11 | 3.85 | 0.092 | 0.83 | 1.43 | 9.02 | 2.13 | 0.86 | 1.54 | 1.80 | 0.07 | 0.08 | 0.19 | 0.57 | 0.76 | 2.26 | 4.47 | 3.71 | 83.00 | 2.58 | 4.45 |
| **AB** | 21-35 | 6.05 | 4.19 | 0.026 | 0.22 | 0.47 | 10.38 | 0.16 | 1.01 | 2.02 | 2.00 | 0.06 | 0.11 | 0.25 | 0.75 | 1.00 | 2.34 | 5.17 | 4.17 | 80.66 | 1.74 | 4.84 |
| **Bg$_1$** | 35-65 | 6.35 | 4.16 | 0.120 | 0.10 | 0.17 | 0.83 | 1.26 | 1.65 | 1.82 | 1.10 | 0.06 | 0.09 | 0.25 | 0.75 | 1.00 | 2.26 | 4.07 | 3.07 | 75.43 | 2.21 | 6.14 |
| **Bg$_2$** | 65-108 | 6.07 | 4.33 | 0.019 | 0.08 | 0.14 | 4.21 | 0.18 | 1.76 | 2.11 | 1.20 | 0.07 | 0.11 | 0.22 | 0.66 | 0.88 | 2.30 | 4.37 | 3.49 | 79.86 | 2.51 | 5.03 |
| **Bg$_3$** | 108-200 | 5.23 | 4.97 | 0.018 | 0.08 | 0.14 | 4.44 | 0.75 | 1.92 | 1.92 | 1.00 | 0.03 | 0.10 | 0.32 | 0.96 | 1.28 | 2.40 | 4.40 | 3.12 | 70.91 | 1.59 | 7.27 |
| | **Mean** | **6.00** | **4.29** | **0.055** | **0.27** | **0.31** | **5.78** | **0.90** | **1.44** | **1.88** | **1.42** | **0.13** | **0.07** | **0.25** | **0.74** | **0.98** | **2.312** | **4.50** | **3.51** | **77.972** | **2.13** | **5.55** |
| **Terrace EO3** | | | | | | | | | | | | | | | | | | | | | | |
| **A** | 0-5 | 5.86 | 3.91 | 0.074 | 0.76 | 1.31 | 10.37 | 1.24 | 0.94 | 2.06 | 2.20 | 0.1 | 0.08 | 0.21 | 0.63 | 0.84 | 2.40 | 5.28 | 4.44 | 84.09 | 1.52 | 3.98 |
| **AB** | 5-34 | 6.45 | 4.28 | 0.025 | 0.38 | 0.66 | 15.20 | 0.08 | 1.48 | 1.92 | 1.30 | 0.17 | 0.08 | 0.14 | 0.42 | 0.56 | 1.95 | 3.93 | 3.87 | 98.47 | 2.04 | 3.56 |
| **BA** | 34-56 | 6.12 | 4.28 | 0.021 | 0.30 | 0.52 | 14.29 | 0.15 | 0.52 | 1.30 | 2.50 | 0.06 | 0.08 | 0.22 | 0.66 | 0.88 | 2.00 | 4.82 | 3.94 | 81.74 | 1.66 | 4.56 |
| **Bg$_1$** | 56-98 | 6.62 | 4.68 | 0.019 | 0.24 | 0.41 | 12.63 | 1.06 | 0.69 | 1.73 | 2.50 | 0.10 | 0.08 | 0.10 | 0.30 | 0.40 | 2.88 | 5.30 | 4.41 | 83.21 | 1.66 | 2.08 |
| **Bg$_2$** | 98-200 | 6.43 | 4.83 | 0.017 | 0.23 | 0.40 | 13.53 | 0.86 | 0.67 | 1.68 | 2.50 | 0.07 | 0.09 | 0.15 | 0.45 | 0.60 | 2.80 | 5.52 | 4.34 | 78.62 | 1.82 | 3.04 |
| | **Mean** | **6.36** | **4.40** | **0.031** | **0.38** | **0.66** | **13.58** | **0.68** | **0.86** | **1.74** | **2.20** | **0.07** | **0.08** | **0.16** | **0.49** | **0.65** | **2.406** | **5.24** | **4.2** | **85.226** | **1.74** | **3.44** |
| **Backswamp EO4** | | | | | | | | | | | | | | | | | | | | | | |
| **A** | 0-4 | 6.44 | 4.35 | 0.037 | 0.63 | 0.09 | 17.07 | 1.48 | 0.96 | 1.92 | 2.00 | 0.10 | 0.07 | 0.03 | 0.09 | 0.12 | 3.05 | 4.21 | 4.09 | 97.15 | 1.66 | 0.71 |
| **B** | 4-84 | 6.49 | 4.46 | 0.042 | 0.56 | 0.97 | 13.33 | 0.16 | 1.44 | 2.16 | 1.50 | 0.07 | 0.08 | 0.02 | 0.06 | 0.08 | 2.60 | 3.89 | 3.81 | 97.94 | 2.06 | 0.51 |
| **C** | 84-100 | 6.65 | 4.52 | 0.039 | 0.46 | 0.79 | 11.79 | 0.71 | 0.23 | 1.20 | 1.30 | 0.05 | 0.08 | 0.04 | 0.12 | 0.16 | 1.88 | 2.79 | 2.63 | 94.26 | 2.86 | 0.59 |
| | **Mean** | **6.54** | **4.44** | **0.039** | **0.55** | **0.95** | **14.05** | **0.78** | **0.88** | **1.76** | **1.6** | **0.07** | **0.08** | **0.03** | **0.09** | **0.12** | **2.51** | **3.63** | **3.51** | **96.45** | **2.19** | **0.88** |

pH(KCL)= pH in Potassium Chloride pH ($H_2O$) = pH in water, OC = Organic carbon, TN = Total Nitrogen, Avail. P = Available Phosphorus, $Mg^{2+}$ = magnesium ion, $Na^+$ = sodium ion, $K^+$ potassium ion, $Ca^{2+}$:$Mg^{2+}$ = calcium magnesium ion ratio, TEB = Total Exchangeable Bases, $AL^{3+}$ + $H^+$ = aluminium hydrogen ion summation, $AL^{3+}$ = aluminium concentration, ECEC-Effective Cation Exchange Capacity, Al.sat =

## 4.6 Discussion

Colour establishes a well-known place in the classification of soils. Soils that are well drained had redder hues and higher chromas, whereas poorly drained soils had yellower hues. Colours of the soils were darker in the surface horizons than the subsurface horizons in all the pedons in the different geomorphic units studied. The darker colours of the surface horizons were caused by organic matter coatings of the mineral grains (Mordi, 1986). The soils of the EO4 (backswamp) were more even in colour while those of the levee crest (EO1) showed marked colour variation. The distinctive variation in colour of the levee crest soils might have been caused by the heterogeneous nature of the pedon materials as shown by the bodacious stratification of the pedons. The colour indicates that the levee crest soils were better drained than the soils of the other geomorphic units. The yellowish red colour of the backswamp soils suggested that the moisture regime included longer periods of saturation than soils in the other geomorphic units. The presence of mottles in the soils horizons was used as an indication of the internal drainage pattern of the soil. Mottling was connected with the reduction and mobilization of iron and manganese (low chroma colours, 10YR3/3; moist) and their subsequent oxidation and precipitation (high chroma colours, 10YR8/3; moist) Clothier *et al.*, (1978), they attributed such reducing and oxidizing conditions to seasonally fluctuating groundwater table or the recurrence of perched water. Mottling was more distinct in soils of the terrace and backswamp (EO3 and EO4) probably due to the nature of the texture and drainage pattern of the area. The mottling nature implied that the soils of the backswamp (EO4,EO4S) and terrace (EO3, EO3S) were subjected to more frequent oxidation-reduction cycles, especially those of the backswamps. The mottles in these soils were an indication of impeded drainage, reduced conditions and poor aeration.

Total porosity increased at epipedons, highest value was observed in the terrace(56.15%) while the levee crest showed the lowest value (53.32%). However, total porosity decreased with depth in all the pedons. Total porosity values were similar to the results obtained by Nnaji *et al.*, (2002) in soils of Nsukka area in the same agro-ecological zone ofSoutheastern Nigeria.

For particle size distribution, texture was generally sandy in the soils of the studied area. Texture was generally coarser in the terrace (EO3, EO3S) and finer in the backswamp. The coarser textures of the terrace (EO3, EO3S) might be attributed to the coarser materials which were usually deposited first during periods of river overflow. They were usually deposited close to the flooding stream. The finer materials wereusually deposited farther away from the stream (Mordi, 1986). There were irregular increases in the percentage clay and sand also with depth.The terrace has the highest mean percentage sand and the lowest mean percentage clay. This may be attributed to the depositional pattern of the stream. The top soil generally has lower bulk density values. This might have been as a result of the higher organic matter content recorded and the uncompacted nature of the surface horizons. In all the soils studied,there were generally increase in bulk density with increase in depth. This might have been due to compaction which resulted from overburden effect of the upper horizons.Bulk densities were lower than critical limits for root restriction (1.75-180 $mg/m^3$) (USDA-NRCS, 1996).

Soil moisture content is the water contained in the soil and is a great regulator of physical, chemical and biological activities in thesoil. It dissolves salts and make up the soil solution, which is important as a medium for supplying differentessential nutrients between the soil solids and the soil solution and, then between soil solution and the plants.

The percentage of soil moisture in the soil samples ranged from 8.32 to 24.65.The soils of backswamp recorded the highest percentage of moisture while the levee crest recorded the least.

The measure of soil pH is an important parameter which helps in identification of chemical nature of the soil (Shalini *et al.*, 2003) as it measures hydrogen ion concentration in the soil to indicate the acidic and alkaline nature of the soil. In Oguta (Egwe), the pH of the soil samples ranged from 5.99 - 6.84 with mean values of 6.31(EO1), 6.00(EO2), 6.36(EO3), 6.54(EO4) while the pH values of surface samples ranged from 5.65-6.49 with mean values of 6.21 (EO1S), 5.97(EO2S),5.85(EO3S), 6.21 (EO4S) (in 1NKCl), indicating the existence of a variety of soils that are acidic to slightly acidicin nature

The soils showed irregular distribution of pH values down the profiles. The pH values were lower in the top horizons of the pedons. This might have been due to the production of organic acids by decomposing organic matter (Mordi, 1986). In general, higher pH values were recorded for coarse textured soils than fine textured soils. The lower pH values of the finer textured soils might have been due to the ability of the finer fractions to bind exchangeable H and Al onto their exchange sites. This agreed with the findings of Soil Survey Staff (1951), that soils rich in clay or organic matter had greater reserve of acidity than sandy soils or those low in organic matter.

The soils of the levee slope had the highest values of exchangeable acidity while the backswamp had the least values. The higher values of exchangeable acidity in the levee slope soils might have been due to their higher aluminum saturation percentage. In all the soils of the study area, the exchangeable acidity was dominated by exchangeable aluminum.The higher exchangeable aluminum could be attributed to the release of aluminum ions from weathering clay minerals. This was in support of the hypothesis of Buol *et al*, (1980) who proposed that clay mineral lattice destruction resulted in release of ions. Also due to the very slow mobility or exchangeable Al in hydromorphic soils (Gottoh, 1976); there was a higher accumulation of the cation in the levee slope soils. The high percentage of aluminum on the exchange sites would cause toxicity problems which will in turn affect crop production. There were irregular distribution of exchangeable acidity and this might be caused as a result of non-homogeneity of the soil parent materials in different geomorphic units.

Potassium (K) is the third most required element by the plants, which plays a key role in water balance inplants or regulation of osmosis (Singh and Tripathi, 1993). It is the most abundant metal cation in plant cell (2to 3 % by dry weight). In Oguta (Egwe), the exchangeable potassium values were in a narrow range, exchangeable sodium and potassium contents were very low in all the soils of the studied area.All the soils fell below critical value of0.2cmol/kg, this is in harmony with the findings of FPDD (1990). Exchangeable calcium was low, and also below the critical value of 4.0cmol/kg as reported by FPDD (1990). Exchangeable Mg was low in all the soils of the studied area. All the soils fell below critical value of 0.5cmol/kg this is in harmony with the findings of(Ibia, 1995).

ECEC varied widely in different soils. The soils recorded low ECEC, below the critical value of 10cmol/kg as reported by Ibia, (1995), and variedirregularly down the slope. The soils of terrace pedon (EO3)and levee crest surface soil (EO1S) recorded the highest ECEC while the backswamp (EO4)has the lowest value of ECEC. The low ECEC in the soils of the studied area shows that the soils will find it difficult to withstand leaching of nutrients because of less clay contents which were the principal colloidal materials that influences ECEC of soils at any given location as a result not well suitable for crop production unless well amended.

Soils of backswamp (EO4) recorded the highest percentage base saturation. This might be due to the youthful nature of the parent material that formed the soils and which may be an indication of the existence of weatherable soil minerals. Base saturation was lowest in the levee slope(EO2) while that of the surface sample recorded the highest value at the levee slope (EO2S) and lowest at the levee crest (EO1S).The base saturation obtained were moderate to high and the mean values were above critical value of 50%as noted by Landon (1984),high base saturation is very desirable in agricultural soils because it shows greater availability of some basic and ammonium ions, which are important macro and secondary plant nutrients (Udoh, 1995). Also these soils were not usually cultivated because of thedifficulty in accessing them during the submergence cycle which lasted for a greater part of the year. The lower base saturation in the levee slope might be due to the coarser texture of the soils. All the pedons had irregular distribution of values down the pits. This irregular distribution might be due to sedimentary nature of the parent materials.

The values of aluminum saturation in all the soils studied ranged from 0.60% to 4.84% (EO1-EO4)in the pedons and 1.63% to 10.15% in the surface samples. The highest percentage was obtained in levee slope(EO2, EO2S) and this might be attributed to the high pH because high aluminum saturationvalues increases the toxicity of the soil, while the lowest was obtained in backswamp (EO4, EO4S). With the exception of pedon EO1 where aluminum saturation decreased down the pedons and surface samples, all other pedons studied had irregular values down the profile pits and the surface samples.

Nitrogen is most often the limiting nutrient for the plant. Plants take up nitrogen generally as nitrates under aerobic conditions and as ammonium ions during anaerobicconditionsgrowth. The nitrogen content is very lowin all the soil samples in the study area. Excess soil moisture content is one of theimportant factors affecting nitrification in water logged soils and is having a major contribution to vary the process. Since excess water is found in water logged areas, soil suppresses the process of nitrification because of deficient oxygen. Unlike in dry soils as in case of the levees however do have enough moisture for the bacterial metabolism and the moistening of such soils rapidly increases the rate of biosynthesis of nitrogen. The surface soils have higher values of N than the pedons. The highest value was recorded in levee slope0.075% (EO2S),0.055%(EO2),followed by backswampwhile the least was recorded in levee crest0.022% (EO1), 0.066% (EO1S), this might be caused by less OM content and leaching.There was irregular distribution of nitrogen down the pedon and geomorphic units all through the soils in the studied area.The higher values of nitrogen in the soils of backswampwere due to slow rate of mineralization of organic materials as a result of prolonged submergence of the soils by water, additionally the soils were not generally cultivated because of the prolonged waterlogged conditions after submergence cycle.

This might have caused the accumulation of organic matter. On the other hand, the lower values of organic matter recorded by soils of the levee crest might be due to quick mineralization and oxidation rate of soil humus. Also was the use of these soils for local agriculture in a shifting cultivation system with rather short fallows period thereby causing depletion of organic matter through burning, vegetation clearance and over cropping.

The importance of organic matter in the soil is implied in the definition of soil, which recognizes fertility status of the soil, as a unique feature distinguishing soil from the parent rock / other non-fertile soils. It increases the soil fertility / nutrient status and controls erosion and runoff of the soil and water, besides it is a major determinant of improved soil structure, moisture content and general nutrient status of the soil.

The percentages of Organic Carbon content in surface soils.The highest organic carbon values were recorded by soils of backswamps (EO4,EO4S), and this might be due to the slow rate of mineralization of organic matter, while the least were recorded by soils of levee slope and levee crest surface sample (EO2, EO1S). Generally, the organic carbon contents of the soils were very low, percentage organic carbon decreased with depth in all the soils of the studied area.

Phosphorus is the second most important macronutrient available in the biological systems, which constitutes more than 1% of the dry organic weight. It is also a second most limiting factor often affecting plant growth,which exists in the soil in both organic and inorganic forms. In the Oguta-Egwe basin, the highest available phosphorous values were obtained in the soils of levee slope (EO2, EO2S) while the lowest values were obtained in the levee crest (EO1, EO1S). Available phosphorous content in the studied area was generally very lowto low.This is in agreement with the findings of Loganathan and sutton (1986), in their study on phosphorous fractions and availability in soils formed on different geological deposits in the Niger Delta area attributed the low P content of the soils of the coastal plain soils to minimum intrusion of marine organisms at the time of deposition of the soils during the late Pleistocene and Oligocene era when the sea level was low. Marine intrusion was minimum and therefore the source of P was mainly the materials brought by the Niger Riverfrom the inlands in the north which were generally low in P. The relatively higher values of available P in the soils of the levee slope (EO2, EO2S) may be attributed to lower P fixation and this might be due to the coarse texture. The higher p values in the surface soils might be due to biocycling of available P and influence of organic matter in the surface soils than the pedons. The distribution of available P with depth in all the pedon of the studied area was irregular and this might be due to the heterogeneous nature of the soil parent materials.

The C/N ratio of the levee crest pedon (EO1) and backswamp surface soil (EO4S) recorded the highest value, (15.68 and 12.58). However, the soils of the levee slopes(EO2, EO2S, 5.78, 7.01) had the lowest values of C/N ratios. The C/N ratio depicts the availability of nitrogen in the organic matter. C/N ratio of about 10% was suggested to be satisfactory for microbial activity and humus decomposition (Kalpage, 1974). The differences in C/N ratios of the soils of various geomorphic units could be attributed to the influence of particle size composition in their mineral fraction. This corresponds to the findings of Ayeni (2012),who stated that increased C/N ratios were found in sandy loam and sandy soils than in clay soils which in effect explains the increased C/N ratios obtained in the soils of levee crest.

The result of the rank correlation among the soil propertiesshowed that correlation co-efficient of the Physico- chemical propertiesof soils in the studied area observedin all the soils of the fourgeomorphic units, clay content had significant positive relationship ($p<0.01$) with organic carbon at the crest soil. There was anegative or positive but a statistically significantrelationship ($P<0.01$) with all the measured attributes of the soils except the correlation among TP, pH, C/N with N, CEC with ECEC, and C/N with Ca/Mg that showed significant correlation at ($P <0.05$).

Variability for the soil properties exhibitedsalient patterns within the studied area. Among the chemical properties, pH, and %Base saturation showed low variations in all the soils of the four physiographic units. However, magnesium had medium variability in the soils of the four geomorphic units while phosphorus and Organic matterindicated high variations in the four geomorphic units. Total porosity and Sand had low variation in all the soils of the four geomorphic units.The highest CV values were found with Organic matter and Phosphorous contents, while the lowest was found with pH (Table 4.14b).

Based on minimum and maximum values of soil properties and CV values, in general, the variability in the soil chemical properties were high. This was likely due to residual effects of fertilization and despite the application of fertilizers by broadcasting of soil pH amendments (lime), acidity in the area was not homogenously neutralized. Continuous fertilizer applications can change the spatial continuity of soil chemical properties (Cambardella *et.al.*, 1994).

The soils are of the order of Inceptisols and Entisols of the USDA soil taxonomy (Soil Survey Staff, 2010), because of the presence of Ochric and Kandic surface and subsurface diagnostic horizons. Soils of levee crest(EO1) Udepts.Levee slope (EO2) and terrace (EO3) were classified into suborder Udults because of the presence of warmer iso-hyperthermic temperature regime and into great group

Eutrudepts, and Hapludults and subgroup Typic Hapludults because of high base saturation. While backswamp (EO4)are of the order of Entisols because of the presence of Ochric epipedon and Kandicsurface and subsurface diagnostic horizons andwere classified into the suborder Aquepts because of their aquic moisture regime and warmer iso-hyperthermic temperature regime and into the great group Endoaquepts and subgroup Typic Endoaquepts because of their high base saturation. When correlated with FAO/UNESCO soil legend,Soils in levee crest were classified as Eutric Cambisol, levee slope (EO2) -terrace(EO3) were classified as Haplic Cambisols, whilebackswamp (EO4) were classified as 'Eutric Fluvisols' because of their high base saturation and hydromorphic properties (the presence of distinct mottles).

Klingebiel and Montgomery (1966) approach was used for the land capability classification of the soils. This system equally made use of data from both field and laboratory analysis, out of the eight land capability classes in this system, only four was met (classII, III, IV, V) in the study area. Soils of Levee crest (EO1) fell into land capability class II, levee slope (EO2,) fell into land capability Ill, terrace (EO3) fell into land capability class iv, has 'w' (wetness) and 'n' (nutrient or fertility) as limitation whereas backswamp (EO4) fell into land capability class v, having 'w'(wetness), 'n' (nutrient or fertility)and 'a' (angle of slope) as limitations.

The soils of levee crest (EO1) levee slope (EO2) and terrace (EO3)were moderately suitable (S2) for cassava, while the soils of backswamp (EO4) showed low (S3) to marginal suitability for cassava production. There was no highly suitable soil for cassava. But levee crest had a higher moderate suitability. Cassava thrives best in moderately to well drained sandy loam soils (FAO; 1977) This land quality characteristics of the mapping units studied agreed with these findings as the levee crest and levee slope soils showed well drained to moderately drained and sandy loam to loamy soil. Also of significance is the low nitrogen content in the levee crests and levee slope which depicts optimum land quality for cassava production (Kosuowei, 2008). The landsuitability classification for swamp/wetland rice showed that the soils (EO1-EO4 had low suitability (S3) for swamp/wetland rice production; the levee crest had the lowest value of low suitability while the backswamp had the highest. Swamp/wetland rice doesn’t thrive well in soils with high permeability or low water-table during the rice growing season. This might have been the cause for it as the drainage class of the mapping units varied from well drained to poorly drained instead of very poorly drained to well drained.

The soils of levee crest (EO1), levee slope (EO2), terrace (EO3, EO3S) and EO4 Backswamp (pedon) were moderately suitable (S2) for maize production, while the soils of backswamp, surfacesshowed low (S3) to marginal suitability for maize production. There was no highly suitable soil for maize. But levee crest had a higher moderate suitability. Maize thrives best in moderately to well drain sandy loam soils.

The land suitability classification for sugarcane showed that the soils (EO1-EO4) had medium or moderate suitability (S2) for sugarcaneproduction; the levee crest had the highest value of medium suitability while the backswamp had the lowest. Sugarcane thrives well in soils with high permeability or low water-table during the growing season. This might have been the cause for it as the drainage class of the mapping units varied from well drained to poorly drain.

The soils in the levee crest, levee slope, and terrace (EO1-EO3, EO1S-EO3S) were classified as Lhk suggesting that the soils were characterized by uniformly loamy (L) soil with acidic reaction (h) and low potassium reserves (K) while the soils of the backswamp were classified as Lghk suggesting that they were characterized by uniformlyloamy and subsoil with water saturation, gley (g) acidic reaction (h) and low potassium reserves (K).

The three land classification systems showed that the mapping units had different constraints. The land capability classification of the soils showed that all soils studied except backswamp fell into arable crop production class (I-V). Land suitability classification for the four crops (rice, maize,cassava and sugarcane) showed that all soils were low to moderately suitable, none was unsuitable. Fertility capability showed that all the soils were suited for agriculturalpurposes.However, all have acid as their overall limitation. All classification systems showed that soils of backswamp had a general problem of water. The LCC showed that backswamp soils EO4,EO4S have wetness (w) as constraint. The LSC showed soils of backswamps as very poorly drained (VPD) and FCC showed them as soils with limitation of gley (g). All three systems were interrelated; however, FCC seems to be more efficient because it specifically incorporates the various physico chemical variables into classification system.The LCC generalizes 'n' as nutrient deficiency without specifications while LSC establishes the site quality for specific type of agricultural activity. The soils of levee crest, levee slope, terrace, and backswamp had low total nitrogen, low organic matter, low available P, low pH, low exchangeable potassium, while the levee crest soils had low exchangeable calcium as possible limitation, the terrace and backswamp had very poor drainage and flood as possible limitations.

# CHAPTER FIVE

## 5.1Conclusions

The soils of Oguta -Egwe were surveyed, characterized, classified and evaluated for their fertility status. The results of the study showed that the soils were slightly acidic, low in total nitrogen, organic matter, organic carbon, available phosphorous and exchangeable (K). The exchangeable magnesium, sodium, and base saturation were low to moderate. The texture is coarser in the soils of the levees (sandy loam) than the backswamp.The drainage varied from well drained to very poorly drained.

Applying soil taxonomy, the soils are classified as Inceptisols and Entisols(Soil Survey Staff 2010). Soils in levee crest (EO1) were classified into suborder Udepts, great group Eutrudepts, and into sub group Typic Eutrudepts. Soils in levee slope (EO2) and terrace (EO3) were classified into suborder Udults, great group Endoaquults, and into subgroup Typic Hapludult (Soil Survey Staff 2010). However, Soils of backswamp (EO4) were classified into suborder 'Aquepts' and great group Endoaquepts, subgroup Typic Endoaquepts (Soil Survey Staff 2010).

These soils were also classified according to FAO/UNESCO legend as Eutric Cambisols, levee crest (EO1), while levee slope (EO2) - terrace (EO3) were classified as Haplic Cambisol, However, backswamp (EO4) were classified as Eutric Fluvisols (FAO/UNESCO, 2006.)

Three land classification systems, land capability, fertility capability and land suitability classifications were used to evaluate the fertility status of the soils. The results of the land capability classification (LCC) showed that the soils of levee crest (EO1,EO1S) fell into land capability class two(II),levee slope (EO2,EO2s) fell into land capability class three (III) while levee crest soils and levee slope(EO1, EO1S and EO2,EO2S) have limitations due to nutrient holding capacity,(n), Terrace (EO3,EO3S) fell into land capability classfour (IV) with wetness (w) and nutrient holding capacity (n) as limitations. Backswamp (EO4,EO4S) soils fell into land capability class five (V) with wetness (w), nutrient holding capacity, (n) and angle of slope (a) as limitations.

The results of the land suitability classification showed that soils of levee crest - backswamp pedons and surface samples (EO1-EO4 and EO1S-EO4S) have low or marginal suitability (S3) for rice production, while the land suitability classification for cassava and maize production showed that soils of levee crest, levee slope, terrace pedon,(EO1-EO3), levee crest surface soil sample, levee slope soil sample (EO1S-EO2S) have moderate suitability (S2) for cassava and maize production.Terrace pedon (EO3), have moderate or medium suitability (S2) while terrace surface soil sample (EO3S)has low or marginal suitability,backswamp pedon and surface samples (EO4,EO4S) have low or marginal suitability (S3) for cassava production, soils of levee crest, levee slope, terrace, and backswamp pedon(EO1-EO4) and levee crest, levee slope and terrace surface samples (EO1S-EO3S) showed moderate or medium suitability (S2) for maize production while backswamp surface sample (EO4S) showed low suitability for maize production, however the land suitability classification for sugarcane showed that soils of levee crest - backswamp pedons and surface samples (EO1-EO4 and EO1S-EO4S) have moderate or medium suitability (S2) for sugarcane production. The major limitations are soil texture and structure, which directly affect water-holding capacity, permeability of the soil and other physical properties. Other limiting factors are soil fertility, measured by CEC, organic matter and total nitrogen content.

The results of fertility capability classification (FCC) showed that the soils in the levees, terrace and backswamp had uniform loamy sand. The major constraints to crops were acidic reaction, K deficiency and gleying.Poor drainage, flooding (3-4 months), acidity (3.99-4.44), low nutrient status were found to be some of the management related problems of the soils.

Based on minimum and maximum values of soil properties and CV values, in general, the variability in soil chemical properties were high, likely due to residual effects of fertilization and despite the application of fertilizers by broadcasting of soil pH amendments, (lime) acidity in the area was not homogenously neutralized.Continuous fertilizer applications can change the spatial continuity of soil chemical properties.

Effective management of the soils through liming, fertilization, mulching has therefore been suggested to improve the productivity of the soils, the supply of potassium can be enriched with garden compost containing 0.48% $K_2O$ or vermin compost containing about 0.7% $K_2O$.

## 5.2 RECOMMENDATION

Below are the suggested recommended management measures for the soils of different geomorphic units in the study area according to the findings of this research.

The soils are low in total nitrogen, available P, organic matter, exchangeable potassium; therefore, it is imperative to make provision for additional nutrient to boost their fertility status. In order to achieve this, inorganic fertilizers and organic manures should be adequately applied to the soils to improve their productive strength. Swamp rice needs elements such as N.P.K, Ca, and Mg. Because the soils are generally low in nitrogen, organo-mineral fertilizers or manure should be used to improve the productive capacity of the soils. Soil fertility can be maintained with organic manure either sole or in combination with inorganic fertilizer. The soils are slightly acidic; therefore proper liming will reduce the acidity and increase effectiveness of fertilizers and growth of arable crops. It will decrease the concentration of toxic elements such as aluminum and create a favorable soil condition for microbial activities.

Mulching should be carried out to improve the physical, chemical, and biological properties of the soils during the dry season. Live or dead mulch could be used for this purpose. Live mulch includes living plants such as creeping cowpeas, melon, groundnut, pumpkin, sweet potato. All these help in reducing evaporation from the soil and in turn lead to increased moisture retention, decreased daily soil temperature and increased microbial activities.

There is the need to understandthe geomorphic units adequately through detailed soil survey and fertility evaluation. When this is carefully done, the soil in each geomorphic unit can then be putto appropriate land use i.e. cultivate the crops that are most suitablefor the land having known its capability and constraints.

## 5.3 CONTRIBUTION TO KNOWLEDGE

This research work will help to determine the application of fertilizer needed for crop’s requirements while also taking cognizance of the nutrients already present in the soil, thus being a cost effective tool for managing fertilizer program.It will equally serve as an aid to understanding geomorphic units.

Also this research would add to the wealth of information on the soils of Oguta and would provide adequate information to land users on the effective management of the soils for increased productivity.

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**Appendix 1**

**PROFILE PIT SHOWING GEOMORPHIC UNITS**



LEVEE CREST PROFILE PIT

LEVEE SLOPE PROFILE PIT

TERRACE PROFILE PIT

BACKSWAMP PROFILE PIT

LEVEE CREST

LEVEE SLOPE

TERRACE

BACKSWAMP

## Appendix 2

# Laboratory Analysis (Procedures)

**Bulk density:** Bulk Density (BD) was measured by the core method (Grossman and Reinsch, 2002). Using a core sampler, soil samples were collected from the four pedons at different depths.(0-200cm, except where water table was stuck) Then the samples in the core sampler were stored nylon and were conveyed to the laboratory.

In the laboratory, the mass of each of the empty crucible was found and as $W_1$. The soil sample was then transferred from the nylon into the crucibles and then reweighed as $W_2$. After which , the crucible with the soil samples were kept in an oven for 24hours at a temperature of 105°C for total dryness of the soil moisture in the soil sample. Then the crucible was removed from the oven and then reweighed as $W_3$. From this, the Bulk Density was calculated as Mass of oven dried soil per volume of core ($g/cm^3$)

**Gravimetric Moisture Content:**The gravimetric moisture content was determined by the use of soil cores to collect samples from the pedons in different geomorphic units. Mass of water in soil sample was determined and later oven dried at a temperature of 105°C until constant weight was achieved. Therefore, Gravimetric moisture content= mass of water in soil/mass of oven dried soil (%)

**Porosity:** Total porosity was determined from the relationship between bulk density and particle density. Whole particle density was taken as 2.65g/cm$^3$. However, porosity was determined on soils of each geomorphic unit based on bulk density values at depths 0 – 200cm except where water table was stocked.

Porosity = 1- bulk density/ particle density (%).

**Particle Size Distribution**

Fifty one grams of soil sample (air-dried) from which organic matter had been removed by the use of hydrogen peroxide was weighed into a milkshake mix-cup into which was added 50ml of calgon (sodium hexametaphosphate solution) and 100ml of distilled water suspension. A multi-mix machine was used to stir the suspension for 15 minutes. It was then transferred to a glass cylinder and made to mark, stoppered and inverted several times. The hydrometer was slided slowly into the suspension until it floats. First hydrometer reading was taken at 40 seconds and temperature of suspension taken with thermometer. The suspension was allowed to set for 3 hours and the hydrometer and temperature readings were taken again and recorded.

The result was corrected to a temperature $20^{O}c$. For every degree above $20^{O}c$, 0.3 was added to hydrometer reading before computation and for under $20^{0}c$, 0.2 was subtracted from hydrometer reading to compensate for the added calgon. The textural classes of the soils were determined from USDA textural triangle based on the percentages of various fractions.

% sand = $\{100H_1 + 0.2 (T_1-20)-2\ 2\}$

% Clay = $(H_2 + 0.3(T_2-20)-2\ 2\}$

%Silt = 100-(%sand+%clay)

Where:

$H_1$ = Initial Hydrometer reading at 40 seconds

$H_2$ = Final hydrometer reading at 3 hours

$T_1$ = Initial temperature reading at 40 seconds

$T_2$ = Final temperature reading at 3 hours

**Total Nitrogen**

10grams of air-dried soil (ground to pass 0.5mm sieve) was weighed into a 500ml macro-kjeldahl flask and 20ml of distilled water added. The flask was swirl for a few minutes and allowed to stand for 30minutes. 10g of $K_2SO_4$-$H_2O$ mixture of catalyst and 10gs of $K_2SO_4^-$ was added. 30ml of Conc.$H_2SO_4^-$ was added through a pipette, Low heat was applied to the flask at the digestion stand, frosting ceased, and the heat was increased to clear digest. The mixture was boiled for 5hours. The flask was then allowed to cool and100ml of water was added. The digest was transferred to a clean 750ml macro-kjeldahl flask. The initial digest flask was washed with 50ml of distilled water and aliquot was transferred to the flask. 50ml of $H_3BO_3$- indicator solution was put into 500ml Erlenmeyer flask and placed under the condenser of the distillation apparatus. The 750ml macro-kjeldahl flask, the initial digest flask was washed 50ml of distilled water and the aliquot was transferred to the flask and placed under condenser of the distillation apparatus. The 750ml kjeldahl flask was attached to the distillation apparatus. 150ml of 10ml NaOH solution was poured through the distillation flask by opening the funnel stopcock. The condenser was kept below $30^{O}$C (cool) to prevent suck-back. 150ml of distillate was collected.

The $NH_4$-N in the distillate was determined by titrating with 0.01M standard HCl using a 25ml burette. The colour change was noted (from green to pink). The percentage total nitrogen was calculated using the following equation

$$\% N = \frac{T \; X \; M \; X \; 14 \; X \; 100}{wt \; of \; soil \; sample}$$

Where

T = Titre Value

M = Molarity of HCl

## Cation Exchange Capacity (CEC)

The exchangeable cations in the soil sample were displaced by ammonium saturation and excess ammonium removed by washing with isopropyl alcohol. The absorbed ammonium was determined by displacing it with sodium chloride followed by distillation of the displaced ammonium into solution of boric acid mixed indicator and the distillate was titrated with standard hydrochloric acid.

**Organic Carbon:**

1.00g of sieved soil sample was used. 10ml of 1N $K_2 \; Cr_2O_7$ solution was introduced into each flask with pipette and swirl gently to disperse the soil.

20mlof Conc. $H_2SO_4$ was added using automatic pipette, directing the stream into the suspension immediately swirl the flask gently until the soil and reagents are mixed, then swirl vigorously for 1 minute and allowed to stand on a sheet of asbestos for about 30minutes. 100ml of distilled water was added after standing for 30minutes, and then 3-4 drops of indicator was added and titrated with 0.5N $FeSO_4$ solution as the end point was reached the solution took on a greenish cast and changed to dark green. At this point $FeSO_4$ was added drop by drop until the colour sharply changed from green to red (Maroon colour) in reflected light against a white background. The result was calculated according to the formula below

% Organic Carbon

$$\text{(Air-dry basis)} = \frac{(\text{Me } K_2 Cr_2 O_7 - \text{Me}FeSO_4) \times 0.003 \times 100 \times f}{\text{g of air-dry soil}}$$

Where correction factor f = 1.33

Me = Normality of solution x ml of solution used

% Organic matter in the soil = % organic carbon x 1.724.

**APPENDIX3**

**Appendix 2: Description of Pedons**
**EO1**

| | |
|---|---|
| Geomorphic unit | Levee Crest |
| Sample Date | 19th August 2014 |
| Lat& Long | $5^0$ 46' 086"N & $6^0$ 49' 345"E |
| Elevation (Alt) | 121 meters |
| Profile No. | EO1 |
| Classification | USDA- Typic Eutrudepts<br>FAO- Eutric Cambisol |
| Topography | Nearly Level, 1% Slope |
| Drainage | Well drained |
| Depth of water table | Beyond 2 meters (200cm) |
| Vegetation/land use | Rainforest/ uncultivated |
| Parent material | Coastal plain sands |
| Climatic info | Rainy & dry season |
| Geology | Benin formation |
| Erosion hazards | Few gully |
| Location | Oguta- Egwe |
| Described by | Nwachukwu Ogechi Mercy, September4th 2014 |

| Horizon | Depth cm | Description |
|---|---|---|
| A | 0-20 | Brown (7.5YR4/4 ;)moist sandy; brown, common, medium distinct prominent mottles;( 7.5YR 3/5cm2P; Moist)weak, fine granular;loose, non- sticky, non-plastic abundant medium roots, smooth diffused boundary. |
| AB20-65 | | Reddish grey(5YR 5/2moist) sandy;reddish,common, medium, distinct, mottles (5YR4/3c2d; moist) strong, granular,very firm, non- sticky, non- plastic, abundant medium roots, few animal activities, diffused boundary. |
| BG1 | 65-120 | Red (2.5YR 5/8moist) sandy; red, few, distinct, mottles(2.5YR3/5;moist)very coarse granular, very firm, non- sticky, non- plastic, medium root, very few animal activities, diffused boundary. |
| BG2120-200 | | Red(10R 4/8; moist) sandy; red, common, medium, prominent mottles (10R 3/6cm2p; moist) very coarse granular, moderate, non- sticky, non- plastic, few roots. |

**EO2**

| | |
|---|---|
| Geomorphic unit | LeveeSlope |
| Sample Date | 19th August 2014 |
| Lat & Long | $5^0$ 46' 369''N & $6^0$ 49' 612''E |
| Elevation (Alt) | 116 meters |
| Profile No. | EO2 |
| Classification | USDA- Typic Hapludults<br>FAO- Haplic Cambisol |
| Topography | Nearly Level, 1.5% Slope |
| Drainage | Moderately well drained |
| Depth of water table | Beyond 2 meters (200cm) |
| Vegetation/land use | Rainforest/ uncultivated |
| Parent material | Coastal Plain sands |
| Climatic info | Rainy & Dry season |
| Geology | Benin Formation |
| Erosion hazards | Few Gully |
| Location | Oguta- Egwe |
| Described by | Nwachukwu Ogechi Mercy, September 4th 2014 |

| Horizon | Depth cm | Description |
|---|---|---|
| A | 0-21 | Dark brown (7.5YR3/3; moist) sandy; dark brown, common, many, medium prominent mottles(7.5YR4/5cm2p; moist) stuctureless fine granular loose non- sticky, non- plastic, abundant root medium, clear smooth boundary. |
| AB | 21-35 | Strong brown (7YR5/8; moist) sandy; common medium distinct strong brown mottles (7YR3/5c2d; moist) weak fine granular, soft friable, non-sticky, non-plastic, abundant root medium, clear smooth boundary. |
| BG1 | 35-65 | Light reddish brown ((5YR6/3; moist) loamy sand,few fine faint light reddishbrown, mottles (5YR2/4f1f;moist) coarse, granular, loose soft firm non- sticky, non- plastic, few medium root, few animal activities, clear smooth boundary. |
| BG2 | 65-108 | Lightred (2.5YR6/6; moist) loamy sand; few fine faint light red mottles (2.5YR4/5; moist) moderate, very coarse granular soft firm, non-sticky, non- plastic, abundant root medium, few animal activities, clear smooth boundary. |
| BG3 | 108-200 | Light red(2.5YR7/8) moist; loamy sand; common many medium prominentlight red mottles (2.5YR6/8;moist)moderate firm, non-sticky, non- plastic, very firm, abundant medium root, few animal activities. |

**EO3**

| | |
|---|---|
| Geomorphic unit | Levee Crest |
| Sample Date | 19th August 2014 |
| Lat & Long | $5^0$ 42' 330"N & $6^0$ 48' 876"E |
| Elevation (Alt) | 111 meters |
| Profile No. | EO3 |
| Classification | USDA- TypicHapludults<br>FAO- HaplicCambisols |
| Topography | Nearly Level, 2% Slope |
| Drainage | Moderately well drained |
| Depth of water table | Beyond 2 meters (200cm) |
| Vegetation/land use | Rainforest/ uncultivated |
| Parent material | Coastal Plain sands |
| Climatic info | Rainy & Dry season |
| Geology | Benin Formation |
| Erosion hazards | Few Gully |
| Location | Oguta- Egwe |
| Described by | Nwachukwu Ogechi Mercy, September 4th 2014 |

| Horizon | Depth cm | Description |
|---|---|---|
| A | 0-5 | very dark grey (7.5YR3/1; moist) sandy; common many medium prominent dark grey mottles (7.5YR4/3; moist)weak fine granular loose non-sticky, non- plastic, abundant medium roots, many micro to intestinal pores, clear smooth boundary. |
| AB | 5-34 | Yellowish red (5YR5/6; moist) sandy; common medium, distinct,yellowish red mottles weak coarse, granular, soft very friable, non-sticky, on- plastic, root medium, few animal activities, clear smooth boundary. |
| BA34-56 | | Reddish yellow (5YR6/8; moist) loamy sand; common medium ,distinct, reddish yellow mottles, weak coarse granular, soft firm, sticky, slightly plastic , medium root, few animal activities clear smooth boundary. |
| BG1 | 56-98 | Reddish brown (5YR5/4; moist), loamy sand;few fine faintreddish brown mottles, moderate, coarse granular, moderate firm, slightly stick, slightly plastic, few medium root, few animal activities. |
| BG2 | 98-200 | Yellowish red (5YR7/8; moist) loamy sand; few fine faint, yellowish red mottles, moderate, very coarse, granular, moderate, firm non- sticky, non- plastic few rootmedium, very few animal activities. |

**EO4**

| | |
|---|---|
| Geomorphic unit | Backswamp |
| Sample Date | 19th August 2014 |
| Lat & Long | $5^0$ 42' 270''N & $6^0$ 48' 869''E |
| Elevation (Alt) | 109 meters |
| Profile No. | EO4 |
| Classification | USDA- Typic Endoaquepts<br>FAO- Eutric Fluvisols |
| Topography | Nearly Level, 3% Slope |
| Drainage | very poorly drained |
| Depth of water table | 1.0 meters (100cm) |
| Vegetation/land use | Swamp forest |
| Parent material | Coastal Plain Sand |
| Climatic info | Rainy & Dry season |
| Geology | Benin Formation |
| Erosion hazards | Few Gully |
| Location | Oguta- Egwe |
| Described by | Nwachukwu Ogechi Mercy, September 4th 2014 |

| Horizon | Depth cm | Description |
|---|---|---|
| A | 0-4 | Yellowish red (5YR6/8; moist) sandy; common many medium prominent yellowish red, mottles, weak coarse granular, loose, non- sticky, non-plastic, abundant medium root, abundant animal activities, clear smooth boundary. |
| B | 4-54 | Yellowish red (5YR5/8; moist) sandy; few distinct yellowish red mottles (5YR2/4; moist), weak coarse granular loosenon- sticky, non-plastic, medium root, few animalactivities diffused wavy boundary. |
| C | 84-100 | Weak red (2.5YR 5/2) moist; sandy; commonmedium distinct, weak red mottles, (2.5YR4/3; moist)weakcoarse granular, loose non -sticky, non -plastic, very few medium roots, very few animal activities. |

# APPENDIX 4

## Land Suitability Classification of the soils in the study Area for Wetland or Swamp Rice Production

**Levee Crest (EO1)**

| | Land Quality Characteristics | | Land | | Unit (S1) 3 | wt (S2) 2 | High | Moderate (S3) 1 | (N1) 0 | Low | Very Low |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Land quality score | | | | 4 | | | | | | | |
| Fertility Status | Organic carbon | % | 1 | - | - | | - | - | 0.31 | | |
| | Tot Nitrogen | % | 1 | - | - | | - | 0.34 | | | |
| | Avail.P | µg/g | 1 | - | - | | - | 0.05 | | | |
| | Exch. K | Cmol/kg | 1 | - | - | | - | 0.05 | | | |
| | Exch.Ca | Cmol/kg | 1 | - | - | | 1.60 | - | | | |
| | pH | - | 1 | 6.31 | - | | - | - | | | |
| | Base Saturation | % | 1 | 86.15 | - | | - | - | | | |
| Workability | | | | | | | | | | | |
| | Soil Consistence | | | | | | | | | | |
| | Moist | - | 1 | - | - | | mfr,ns.np | | | | |
| | Wet | - | 1 | - | - | | ns,np | - | | | |
| Toxicity | | | | | | | | | | | |
| | ESP | % | 2 | 2.13 | - | | - | - | | | |
| Wetness | | | | | | | | | | | |
| | 6 | | | | | | | | | | |
| | Drainage Class | - | 3 | - | - | | - | WD | | | |
| | Flood Duration | Months | 2 | - | - | | - | <2 | | | |
| | Ground $H_2O$ table | cm | 3 | - | - | | - | >200 | | | |
| Climate | | | | | | | | | | | |
| | Annual Rainfall | mm | 2 | 2500 | - | | - | - | | | |
| Soil Physical condition | | | 4 | | | | | | | | |
| | Text Class | - | 3 | - | - | | - | SL | | | |
| | Soil depth | cm | 3 | 200 | - | | - | - | | | |
| | Clay | % | 2 | - | - | | - | 16.0 | | | |

S1 = High Suitability

S2 = Moderate or Medium Suitability

S3 = Low or Marginal Suitability

N1 = Very Low or not Suitable

## Land Suitability Classification of Soils in the study Area for Wetland or Swamp Rice Production

**Levee Slope (EO2)**

| Land Quality Characteristics | Land | Unit | wt | High (S1) 3 | Moderate (S2) 2 | Low (S3) 1 | Very Low (N1) 0 |
|---|---|---|---|---|---|---|---|
| Land quality score | | | 4 | | | | |
| Fertility Status | Organic carbon | % | 1 | - | - | - | 0.27 |
| | Tot Nitrogen | % | 1 | - | - | - | 0.055 |
| | Avail.P | µg/g | 1 | - | - | - | 0.90 |
| | Exch. K | Cmol/kg | 1 | - | 0.13 | - | - |
| | Exch.Ca | Cmol/kg | 1 | - | - | 1.88 | - |
| | pH | - | 1 | 5.23 | - | - | - |
| | Base Saturation | % | 1 | 80.64 | - | - | - |
| Workability | | | | | | | |
| | Soil Consistence Moist | - | 1 | - | - | Sh,ml | - |
| | | | mfi | | | | |
| | Wet | - | 1 | - | - | ns,np | - |
| Toxicity | | | | | | | |
| | ESP | % | 2 | 6 | - | 1.86 | - |
| Wetness | | | | | | | |
| | | | 6 | | | | |
| | Drainage Class | - | 3 | - | - | MWD | - |
| | Flood Duration | Months | 2 | - | - | - | <2 |
| | Ground $H_2O$ table | cm | 3 | - | - | - | >200 |
| Climate | | | | | | | |
| | Annual Rainfall | mm | 2 | 2,500 | - | - | - |
| Soil Physical condition | | | 4 | | | | |
| | Textural Class | - | 3 | - | - | L,SL | - |
| | Soil depth | cm | 3 | 200 | - | - | - |
| | Clay | % | 2 | - | - | - | 16.0 |

S1 = High Suitability
S2 = Moderate or Medium Suitability
S3 = Low or Marginal Suitability

N1 = Very Low or not Suitable

## Land Suitability Classification of soils the study Area for Wetland or Swamp Rice Production

**Terrace (EO3)**

| Land Quality | Land Characteristics | Unit | wt | High (S1) 3 | Moderate (S2) 2 | Low (S3) 1 | Very Low (N1) 0 |
|---|---|---|---|---|---|---|---|
| Land quality score | | | 4 | | | | |
| Fertility Status | Organic carbon | % | 1 | - | - | - | 0.38 |
| | Tot Nitrogen | % | 1 | 0.031 | - | - | - |
| | Avail.P | µg/g | 1 | - | - | 0.68 | - |
| | Exch. K | Cmol/kg | 1 | - | - | 0.07 | - |
| | Exch.Ca | Cmol/kg | 1 | - | - | - | 1.74 |
| | pH | - | 1 | 6.36 | - | - | - |
| | Base Saturation | % | 1 | 85.82 | - | - | - |
| Workability | | | | | | | |
| | Soil Consistence Moist | - | 1 | - | - | sh,ml | - |
| | Wet | - | 1 | - | - | mfi | - |
| Toxicity | | | | | | | |
| | ESP | % | 2 | - | - | - | 1.74 |
| Wetness | 6 | | | | | | |
| | Drainage Class | - | 3 | - | PD | - | - |
| | Flood Duration | Months | 2 | - | <2 | - | - |
| | Ground $H_2O$ table | | cm | 3 | 200 - | | - |
| Climate | | | | | | | |
| | Annual Rainfall | mm | 2 | 2,500 | - | - | - |
| Soil Physical condition | | | 4 | | | | |
| | Textural Class | - | 3 | - | - | L,SL | - |
| | Soil depth | cm | 3 | 200 | - | - | - |
| | Clay | % | 2 | - | | - | 16.0 |

S1 = High Suitability

S2 = Moderate or Medium Suitability

S3 = Low or Marginal Suitability

N1 = Very Low or not Suitable

## Land Suitability Classification of Soils in the study Area for Wetland or Swamp Rice Production

**Backswamp (EO4)**

| Land Quality | Land Characteristics | Unit | wt | High (S1) 3 | Moderate (S2) 2 | Low (S3) 1 | Very Low (N1) 0 |
|---|---|---|---|---|---|---|---|
| Land quality score | | | 4 | | | | |
| Fertility Status | Organic carbon | % | 1 | - | - | - | 0.55 |
| | Tot Nitrogen | % | 1 | 0.039 | - | - | - |
| | Avail.P | µg/g | 1 | - | - | - | 0.07 |
| | Exch. K | Cmol/kg | 1 | 0.78 | - | | - |
| | Exch.Ca | Cmol/kg | 1 | - | - | 1.76 | - |
| | pH | - | 1 | - | - | 6.54 | - |
| | Base Saturation | % | 1 | 97.58 | - | - | - |
| Workability | | | 2 | | | | |
| | Soil Consistence | | | | | | |
| | Moist | - | 1 | - | - | sh, | - |
| | Wet | - | 1 | - | - | mfi | - |
| Toxicity | | | | | | | |
| | ESP | % | 2 | - | - | - | 1.63 |
| Wetness | | | 6 | | | | |
| | Drainage Class | - | 3 | - | - | VPD | - |
| | Flood Duration | Months | 2 | >4 | - | - | - |
| | Ground $H_2O$ table | cm | 3 | | - | 100 | - |
| Climate | | | | | | | |
| | Annual Rainfall | mm | 2 | 2,500 | - | - | - |
| Soil Physical condition | | | 4 | | | | |
| | Textural Class | - | 3 | - | - | S,SL | - |
| | Soil depth | cm | 3 | - | - | 100 | - |
| | Clay | % | 2 | - | - | - | 16.0 |

S1 = High Suitability

S2 = Moderate or Medium Suitability

S3 = Low or Marginal Suitability

N1 = Very Low or not Suitable

# Appendix 4
# Land Suitability Classification of Soils in the study Area for Cassava Production

**Levee Crest (EO1)**

| Land Quality | Land Characteristics | Unit | wt | High (S1) 3 | Moderate (S2) 2 | Low (S3) 1 | Very Low (N1) 0 |
|---|---|---|---|---|---|---|---|
| Land quality score | | | 4 | | | | |
| Fertility Status | Organic carbon | % | 1 | - | - | - | 0.34 |
| | Tot Nitrogen | % | 1 | 0.022 | - | - | - |
| | Avail.P | µg/g | 1 | - | - | 0.50 | - |
| | Exch. K | Cmol/kg | 1 | - | - | - | 0.05 |
| | pH | - | 1 | 6.31 | - | - | - |
| | Base Saturation | % | 1 | 86.15 | - | - | - |
| Workability | | | 6 | | | | |
| | Soil Consistence | | | | | | |
| | Dry | - | 2 | - | L,h | - | - |
| | Moist | - | 2 | mfr | - | - | - |
| | wet | | 2 | | sh, L, mfr | - | - |
| Drainage | | | | | | | |
| | Drainage Class | - | 3 | WD | - | - | - |
| | Porosity | % | 2 | - | - | 53.32 | - |
| | Abundant/cm$^2$ | | | | | | |
| | Ground $H_2O$ table | cm | 3 | 200 | - | - | - |
| Avail. Water | | | 5 | | | | |
| | Text. Class | - | 3 | - | SL | - | - |
| Rooting Depth | | | 4 | | | | |
| | Soil depth | cm | 3 | 200 | - | - | - |

S1 = High Suitability
S2 = Moderate or Medium Suitability
S3 = Low or Marginal Suitability
N1 = Very Low or not Suitable

## Land Suitability Classification of Soils in the study Area for Cassava Production

**Levee Slope(EO2)**

| Land Quality | Land Characteristics | Unit | wt | High (S1) | Moderate (S2) | Low (S3) | Very Low (N1) |
|---|---|---|---|---|---|---|---|
| | | | | 3 | 2 | 1 | 0 |
| Land quality score | | | 4 | | | | |
| Fertility Status | Organic carbon | % | 1 | - | - | - | 0.27 |
| | Tot Nitrogen | % | 1 | 0.055 | - | - | - |
| | Avail.P | µg/g | 1 | - | - | - | 0.90 |
| | Exch. K | Cmol/kg | 1 | - | - | - | 0.13 |
| | pH | - | 1 | - | 6.00 | - | - |
| | Base Saturation | % | 1 | 80.64 | - | - | - |
| Workability | | | 6 | | | | |
| | Soil Consistence | | | | | | |
| | Dry | - | 2 | - | L,h | - | - |
| | Moist | - | 2 | - | sh | - | - |
| | Wet | | 2 | - | L,mfi, np, ns | - | - |
| Drainage | | | 6 | | | | |
| | Drainage Class | - | 3 | WD | - | - | - |
| | Porosity | % | 2 | - | - | 55.02 | 0 |
| | Abundant/$cm^2$ | | | | | | |
| | Ground $H_2O$ table | cm | 3 | >200 | - | - | - |
| Avail. Water | | | 5 | | | | |
| | Text. Class | - | 3 | - | - | - | S, LS |
| Rooting Depth | | | 4 | | | | |
| | Soil depth | cm | 3 | >200 | - | - | - |

| | | |
|---|---|---|
| S1 | = | High Suitability |
| S2 | = | Moderate or Medium Suitability |
| S3 | = | Low or Marginal Suitability |
| N1 | = | Very Low or not Suitable |

## Land Suitability Classification of soils in the study Area for Cassava Production

**Terrace (EO3)**

| Land Quality | Land Characteristics | Unit | wt | High (S1) 3 | Moderate (S2) 2 | Low (S3) 1 | Very Low (N1) 0 |
|---|---|---|---|---|---|---|---|
| Land quality score | | | 4 | | | | |
| Fertility Status | Organic carbon | % | 1 | - | - | - | 0.38 |
| | Tot Nitrogen | % | 1 | 0.31 | - | - | - |
| | Avail.P | µg/g | 1 | - | - | - | 0.68 |
| | Exch. K | Cmol/kg | 1 | - | - | - | 0.07 |
| | pH | - | 1 | 6.36 | - | - | - |
| | Base Saturation | % | 1 | 85.82 | - | - | - |
| Workability | | | 6 | | | | |
| | Soil Consistence | | | | | | |
| | Dry | - | 2 | - | l ,h | - | - |
| | Moist | - | 2 | - | sh | - | - |
| | Wet | | 2 | - | mfi, np,ns | - | - |
| Drainage | | | 6 | | | | |
| | Drainage Class | - | 3 | - | - | - | PD |
| | Porosity | % | 2 | - | - | 56.18 | - |
| | Abundant/$cm^2$ | | | | | | |
| | Ground $H_2O$ table | cm | 3 | >200 | - | - | - |
| Avail. Water | | | 5 | | | | |
| | Text. Class | - | 3 | - | SL,LS | - | - |
| Rooting Depth | | | 4 | | | | |
| | Soil depth | cm | 3 | 200 | - | - | - |

S1 = High Suitability
S2 = Moderate or Medium Suitability
S3 = Low or Marginal Suitability
N1 = Very Low or not Suitable

## Land Suitability Classification of Soils in the study Area for Cassava Production

**Backswamp (EO4)**

| Land Quality | Land Characteristics | Unit | wt | High (S1) | Moderate (S2) | Low (S3) | Very Low (N1) | |
|---|---|---|---|---|---|---|---|---|
| | | | | 3 | 2 | 3 | 0 | |
| Land quality score | | | 4 | | | | | |
| Fertility Status | Organic carbon | % | 1 | - | - | 0.55 | - | |
| | Tot Nitrogen | % | 1 | 0.039 | - | - | - | |
| | Avail.P | µg/g | 1 | - | - | - | 0.78 | |
| | Exch. K | Cmol/kg | 1 | - | - | - | 0.07 | |
| | pH | - | 1 | 6.54 | - | - | 0 | |
| | Base Saturation | % | 1 | 97.58 | - | - | - | |
| Workability | | | 6 | | | | | |
| | Soil Consistence | | | | | | | |
| | Dry | - | 2 | - | l,h | - | - | |
| | Moist | - | 2 | - | - | mvfi | - | |
| | Wet | | 2 | - | - | n,p | - | |
| Drainage | | | 6 | | | | | |
| | Drainage Class | - | 3 | - | - | - | VPD | |
| | Porosity | % | 2 | - | - | 53.96 | - | |
| | Abundant/cm$^2$ | | | | | | | |
| | Ground $H_2O$ table | | cm | 3 | 100 - | | - | - |
| | Avail. Water | | | | 5 | | | |
| | Text. Class | - | 3 | - | SL,LS | - | - | |
| Rooting Dept | | | | | | 4 | | |
| | Soil depth | cm | 3 | 100 | | - | - | |

S1 = High Suitability
S2 = Moderate or Medium Suitability
S3 = Low or Marginal Suitability
N1 = Very Low or not Suitable

# Appendix 5
## Land Suitability Classification of Soils in the study Area for Maize Production

**LEVEE CREST EO1**

| | Land Quality | Land | | Unit | wt | High | Moderate | | Low | Very Low |
|---|---|---|---|---|---|---|---|---|---|---|
| | Characteristics | | | (S1) | (S2) | | (S3) | (N1) | | |
| | 3 2 | | 1 | 0 | | | | | | |
| Land quality score | | | 4 | | | | | | | |
| Fertility Status | Organic carbon | % | 1 | - | - | | - | 0.34 | | |
| | Ca | Cmol/kg | 1 | - | - | | 1.60 | - | | |
| | Avail.P | µg/g | 1 | - | - | | 0.50 | - | | |
| | Exch. K | Cmol/kg | 1 | - | - | | - | 0.05 | | |
| | pH | - | 1 | 6.31 | - | | - | - | | |
| | Base Saturation | % | 1 | 86.15 | - | | - | - | | |
| Workability | | | 6 | | | | | | | |
| | Soil Consistence | | | | | | | | | |
| | Dry | | - | 2 | - | L,h | - | - | | |
| | Moist | - | 2 | mfr | - | | - | - | | |
| | wet | | 2 | - | sh, L, mfr | | - | - | | |
| Drainage | | | 6 | | | | | | | |
| | Drainage Class | - | 3 | WD | - | | - | - | | |
| | Porosity | % | 2 | - | - | | 53.32 | - | | |
| | Abundant/cm$^2$ | | | | | | | | | |
| | Ground $H_2O$ table | cm | 3 | 200 | - | | - | - | | |
| Avail. Water | | | 5 | | | | | | | |
| | Text. Class | - | 3 | - | SL,LS | | - | - | | |
| Rooting Depth | | | 4 | | | | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Soil depth | cm | 3 | 200 | - | - | - |

S1 = High Suitability
S2 = Moderate or Medium Suitability
S3 = Low or Marginal Suitability
N1 = Very Low or not Suitable

## Land Suitability Classification of Soils in the study Area forMaize Production

**Levee Slope (EO2)**

| Land Quality | Land Characteristics | Unit | wt | High (S1) | Moderate (S2) | Low (S3) | Very Low (N1) |
|---|---|---|---|---|---|---|---|
| | | | | 3 | 2 | 1 | 0 |
| Land quality score | | | 4 | | | | |
| Fertility Status | Organic carbon | % | 1 | - | - | - | 27 |
| | Ca | cmol/kg | 1 | - | - | 1.88 | - |
| | Avail.P | µg/g | 1 | - | - | - | 0.90 |
| | Exch. K | Cmol/kg | 1 | - | - | - | 0.13 |
| | pH | - | 1 | - | 6.00 | - | - |
| | Base Saturation | % | 1 | 80.64 | - | - | - |
| Workability | | | 6 | | | | |
| | Soil Consistence | | | | | | |
| | Dry | - | 2 | - | L,h | - | - |
| | Moist | - | 2 | - | sh | - | - |
| | Wet | | 2 | - | L,mfi, np, ns | - | - |
| Drainage | | | 6 | | | | |
| | Drainage Class | - | 3 | WD | - | - | - |
| | Porosity | % | 2 | - | - | 55.02 | 0 |
| | Abundant/$cm^2$ | | | | | | |
| | Ground $H_2O$ table | cm | 3 | >200 | - | - | - |
| Avail. Water | | | 5 | | | | |
| | Text. Class | - | 3 | - | S, LS | - | - |
| Rooting Depth | | | 4 | | | | |
| | Soil depth | cm | 3 | >200 | - | - | - |

S1 = High Suitability

S2 = Moderate or Medium Suitability
S3 = Low or Marginal Suitability
N1 = Very Low or not Suitable

## Land Suitability Classification of soils in the study Area for Maize Production

**Terrace (EO3)**

| Land Quality | Land Characteristics | Unit | wt | High (S1) 3 | Moderate (S2) 2 | Low (S3) 1 | Very Low (N1) 0 |
|---|---|---|---|---|---|---|---|
| Land quality score | | | 4 | | | | |
| | Organic carbon | % | 1 | - | - | - | 0.38 |
| | Ca | cmol/kg | 1 | - | - | 1.74 | - |
| | Avail.P | µg/g | 1 | - | - | - | 0.68 |
| | Exch. K | Cmol/kg | 1 | - | - | - | 0.07 |
| | pH | - | 1 | 6.36 | - | - | - |
| | Base Saturation | % | 1 | 8.82 | - | - | - |
| Workability | | | 6 | | | | |
| | Soil Consistence | | | | | | |
| | Dry | - | 2 | - | l ,h | - | - |
| | Moist | - | 2 | - | sh | - | - |
| | Wet | | 2 | - | mfi, np,ns | - | - |
| Drainage | | | 6 | | | | |
| | Drainage Class | - | 3 | - | - | - | PD |
| | Porosity | % | 2 | - | - | 56.18 | - |
| | Abundant/cm$^2$ | | | | | | |
| | Ground $H_2O$ table | cm | 3 | - | 100 | - | - |
| Avail. Water | | | 5 | | | | |
| | Text. Class | - | 3 | - | S, LS | - | - |
| Rooting Depth | | | 4 | | | | |
| | Soil depth | cm | 3 | 200 | - | - | - |

S1 = High Suitability
S2 = Moderate or Medium Suitability
S3 = Low or Marginal Suitability
N1 = Very Low or not Suitable

## Land Suitability Classification of Soils in the study Area for Maize Production

| Land Quality | **Backswamp (EO4)** Land Characteristics | Unit | wt | High (S1) | Moderate (S2) | Low (S3) | Very Low (N1) |
|---|---|---|---|---|---|---|---|
| | | | | 3 | 2 | 3 | 0 |
| Land quality score | | | 4 | | | | |
| Fertility Status | Organic carbon | % | 1 | - | - | 0.55 | - |
| | Ca | Cmol/kg | 1 | 0.039 | - | - | - |
| | Avail.P | µg/g | 1 | - | - | - | 0.78 |
| | Exch. K | Cmol/kg | 1 | - | - | - | 0.07 |
| | pH | - | 1 | 6.54 | - | - | - |
| | Base Saturation | % | 1 | 97.58 | - | - | - |
| Workability | | | 6 | | | | |
| | Soil Consistence | | | | | | |
| | Dry | - | 2 | - | l,h | - | - |
| | Moist | - | 2 | - | - | mvfi | - |
| | Wet | | 2 | - | - | n,p | - |
| Drainage | | | 6 | | | | |
| | Drainage Class | - | 3 | - | - | - | VPD |
| | Porosity | % | 2 | - | - | 53.96 | - |
| | Abundant/$cm^2$ | | | | | | |
| | Ground $H_2O$ table | cm | 3 | 100 | - | - | - |
| Avail. Water | | | 5 | | | | |
| | Text. Class | - | 3 | - | S, LS | - | - |
| Rooting Depth | | | 4 | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| Soil depth | cm | 3 | - | 100 | - | - |

S1 = High Suitability
S2 = Moderate or Medium Suitability
S3 = Low or Marginal Suitability
N1 = Very Low or not Suitable

# Appendix 7

## Land Suitability Classification of Soils in the study Area for Sugarcane Production

**Levee Crest (EO1)**

| Land Quality | Land Characteristics | Unit | wt | High (S1) | Moderate (S2) | Low (S3) | Very Low (N1) |
|---|---|---|---|---|---|---|---|
| | 3 2 | | 1 | 0 | | | |
| Land quality score | | | 4 | | | | |
| Fertility Status | Organic carbon | % | 1 | - | - | - | 0.34 |
| | Ca | Cmol/kg | 1 | - | - | 1.60 | - |
| | Avail.P | µg/g | 1 | - | - | 0.50 | - |
| | Exch. K Cmol/kg | 1 | - | - | - | 0.05 | |
| | pH | - | 1 | 6.31 | - | - | - |
| | Base Saturation | % | 1 | 86.15 | - | - | - |
| Workability | | | 6 | | | | |
| | Soil Consistence | | | | | | |
| | Dry | - | 2 | - | L,h - | - | |
| | Moist | - | 2 | mfr | - | - | - |
| | wet | | 2 | - | sh, L, mfr | - | - |
| Drainage | | | 6 | | | | |
| | Drainage Class | - | 3 | WD | - | - | - |
| | Porosity | % | 2 | - | - | 53.32 | - |
| | Abundant/$cm^2$ | | | | | | |
| | Ground $H_2O$ table | cm | 3 | 200 | - | - | - |
| Avail. Water | | | 5 | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Text. Class | - | 3 | - | SL,LS | - | - |
| Rooting Depth | | | 4 | | | | |
| | Soil depth | cm | 3 | 200 | - | - | - |

S1 = High Suitability
S2 = Moderate or Medium Suitability
S3 = Low or Marginal Suitability
N1 = Very Low or not Suitable

# Land Suitability Classification of Soils in the study Area for Sugarcane Production

**Levee Slope (EO2)**

| Land Quality | Land Characteristics | Unit | wt | High (S1) | Moderate (S2) | Low (S3) | Very Low (N1) |
|---|---|---|---|---|---|---|---|
| | | | | 3 | 2 | 1 | 0 |
| Land quality score | | | 4 | | | | |
| Fertility Status | Organic carbon | % | 1 | - | - | - | 0.27 |
| | Ca | cmol/kg | 1 | - | - | 1.88 | - |
| | Avail.P | µg/g | 1 | - | - | - | 0.90 |
| | Exch. K | Cmol/kg | 1 | - | - | - | 0.13 |
| | pH | - | 1 | - | 6.00 | - | - |
| | Base Saturation | % | 1 | 80.64 | - | - | - |
| Workability | | | 6 | | | | |
| | Soil Consistence | | | | | | |
| | Dry | - | 2 | - | L,h | - | - |
| | Moist | - | 2 | - | sh | - | - |
| | Wet | | 2 | - | L,mfi, np, ns | - | - |
| Drainage | | | 6 | | | | |
| Drainage Class - | 3 WD | - | | - | - | | |
| | Porosity | % | 2 | - | - | 55.02 | 0 |
| | Abundant/cm$^2$ | | | | | | |
| | Ground $H_2O$ table | cm | 3 | >200 | - | - | - |
| Avail. Water | | | 5 | | | | |
| | Text. Class | - | 3 | - | S, LS | - | - |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Rooting Depth | | | 4 | | | | |
| | Soil depth | cm | 3 | >200 | - | - | - |

S1 = High Suitability
S2 = Moderate or Medium Suitability
S3 = Low or Marginal Suitability
N1 = Very Low or not Suitable

## Land Suitability Classification of soils in the study Area for Sugarcane Production

**Terrace (EO3)**

| Land Quality | Land Characteristics | Unit | wt | High (S1) | Moderate (S2) | Low (S3) | Very Low (N1) |
|---|---|---|---|---|---|---|---|
| | | | | 3 | 2 | 1 | 0 |
| Land quality score | | | 4 | | | | |
| Fertility Status | Organic carbon | % | 1 | - | - | - | 0.38 |
| | Ca | cmol/kg | 1 | - | - | 1.74 | - |
| | Avail.P | µg/g | 1 | - | - | - | 0.68 |
| | Exch. K | Cmol/kg | 1 | - | - | - | 0.07 |
| | pH | - | 1 | 6.36 | - | - | - |
| | Base Saturation | % | 1 | 8.82 | - | - | - |
| Workability | | | 6 | | | | |
| | Soil Consistence | | | | | | |
| | Dry | - | 2 | - | l ,h | - | - |
| | Moist | - | 2 | - | sh | - | - |
| | Wet | | 2 | - | mfi, np,ns | - | - |
| Drainage | | | 6 | | | | |
| | Drainage Class | - | 3 | - | - | - | PD |
| | Porosity | % | 2 | - | - | 56.18 | - |
| | Abundant/cm$^2$ | | | | | | |
| | Ground $H_2O$ table | cm | 3 | - | 100 | - | - |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Avail. Water | | | | | 5 | | | | | |
| | | | Text. Class | | - | 3 | - | S, LS | | - | - |
| | Rooting Depth | | | | | 4 | | | | | |
| | | | Soil depth | | cm | 3 | 200 | - | | - | - |

S1 = High Suitability
S2 = Moderate or Medium Suitability
S3 = Low or Marginal Suitability
N1 = Very Low or not Suitable

## Land Suitability Classification of Soils in the study Area for Sugarcane Production

| | | **Backswamp (EO4)** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Land Quality | | Land Characteristics | | Unit | wt | High (S1) | Moderate (S2) | | Low (S3) | Very Low (N1) |
| | | | 3 | 2 | | 3 | 0 | | | | |
| | Land quality score | | | | | 4 | | | | | |
| | Fertility Status | | Organic carbon r | | % | 1 | - | - | | 0.55 | - |
| | | Ca | Cmol/kg | | 1 | 0.039 | - | | - | - | |
| | | Avail.P | | µg/g | 1 | - | - | | - | 0.78 | |
| | | Exch. K | | Cmol/kg | 1 | - | - | | - | 0.07 | |
| | | pH | | - | 1 | 6.54 | - | | - | - | |
| | | Base Saturation | | % | 1 | 97.58 | - | | - | - | |
| Workability | | | | | 6 | | | | | | |
| | | Soil Consistence | | | | | | | | | |
| | | Dry | | - | 2 | - | l,h | | - | - | |
| | | Moist | | - | 2 | - | - | | mvfi | - | |
| | | Wet | | | 2 | - | - | | n,p | - | |
| Drainage | | | | | 6 | | | | | | |
| | | Drainage Class | | - | 3 | - | - | | - | VPD | |
| | | Porosity | | % | 2 | - | - | | 53.96 | - | |
| | | Abundant/$cm^2$ | | | | | | | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Ground $H_2O$ table | cm | 3 | 100 | - | | - | - |
| Avail. Water | | | 5 | | | | | |
| | Text. Class | - | 3 | - | S, LS | | - | - |
| Rooting Depth | | | 4 | | | | | |
| | Soil depth | cm | 3 | - | 100 | | - | - |

S1 = High Suitability
S2 = Moderate or Medium Suitability
S3 = Low or Marginal Suitability
N1 = Very Low or not Suitable

# APPENDIX 8

## Summary of Fertility Capability Classification System (Sanchez et al, 1982)

The three categorical levels are Type, Substrata, and Modifiers (15), Class designations from the three levels are

**Type:** This signifies the texture of the plow layer or surface whichever is shallower.

S - Sandy topsoil: Loamy sand & sands (USSDA Definition)

L - Loamy topsoil : <35% Clay but not loamy sand or sand.

C - Clay topsoil:>35% Clay.

O - Organic Soil: >30% O.M to a depth of 50cm or more.

**Substrata Type:** This signifies the texture of the sub-soil, which is used when there is a marked texture change from the surface, or when a hard root-restricting layer is seen within the depth of 50cm.

S - Sandy Subsoil: texture as in type

L - Loamy Subsoil: texture as in type

C - Clay Subsoil: texture as in type

R - Rock or other hard root restricting layer.

Modifiers: In a situation whereby more than one criterion is listed as modifier for each sample, only one needs to be met. Here the first listed criterion is the most desirable one to be used if data are available. The remaining criteria are shown and used where data are limiting.

g = (gley): soil or mottles >2 Chroma within 60cm depth of the soil surface and bellow all A horizons, or soil saturated with water for >60 days in most years.

d = (dry): UStic, aridic, or xeric soil moisture regimes (subsoil dry >90 cumulative days per year within 20cm>60cm depth).

e = (low cation exchange capacity): applies only to plow layer or surface 20cm, whichever is shallower. CEC<4meg/100g soil by bases+KCl extractable Al (effective CEC).or CEC < 7meg/100g soil by cations + Al ±H at pH 8.2.

a = (aluminum toxicity): >60% Al Sat. on CEC by cations at pH7 within 50cm of soil surface, pH< 5.0 in 1:2:5 1-

120 within 50cm, except in organic soils where pH must be less than 4.7 .

h = (acid): 10-60% Al saturation of Fe effective CEC within 50cm of soil surface. or pH in 1:1 $H_2O$ between 5.0 and 6.0

i = (high P-fixation by iron): % free $Fe_2O_3$/ %clay> 0.15 and more than 35 clay, or hues of 7.5YR or redder and granular structure. This is used for clay types alone. It applies only to plow-layer or surface 20cm of soil surface, whichever is shallower.

x = (x-ray amorphous): pH> 10 on 1N NaF, or positive to field NaF test, or other indirect evidences of allophane dominance in the clay fraction.

l = (gravel): a prime (') denotes 15-35% gravel or coarser (>2mm) particle by volume to any type, substrata type texture, two prime ('') denotes >35% gravel or coarser (>2mm) particles by volume.

v = (vertisols): very strictly plastic clay: > 35% clay and 50% of 2:1 expanding clays, or severe topsoil shrinking and swelling k =(low k reserves): ,100% weatherable minerals in silt and sand fraction within 50cm of the soil surface, or exchangeable k,0.20cmol/kg, or k,2%of 0.20cmol/kg, or k,2% of bases: 10cmol/kg.

b =(basis reaction): free $CaCO_3$ within50cm of soil surface (effervescence with HCl), or pH>7.3

s =(salinity) : >4mhos/cm ECEC within lm of the surface.

n =(natric):> 15% Na-saturation CEC within 50cm of the surface.

c =(clay): pH in 1:1 $H_2O$ is <3.6 after drying and jarosite mottles with hues of 2.5Y or yellower and chromas 6 or more are present within 60cm of the soil surface.

f =(low base saturation): % base saturation<50%.

% =(slope): where it is desirable to show slope with the FCC, the slope range percentages can be placed in parenthesis after the last condition modifier (e.g. sb 1-6)

The FCC units lists the type and substrata type (if present) in capital letters and the modifiers in low case letters. The absence of modifiers suggests no major fertility limitations other than nitrogen deficiency.