NITROGEN FORMS AND FERTILITY STATUS OFSELECTED FLOODPLAIN SOILS IN IMO STATE, SOUTH – EAST NIGERIA

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CERTIFICATION

This is to certify that this work "**Nitrogen Forms and Fertilkity Status of Selecteed Floodplain Soils in Imo State, South-East Nigeria**" was carried out by I Azuike.Kelechi Charity (20174081538) in partial fulfillment for the award of (M.Sc in Soil Chemistry in the Department of Soil Science and Technology) of the Federal University of Technology, Owerri

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DEDICATION

This project work is dedicated to the Almighty God for having led me thus far and for his Goodness, Faithfulness and Mercy towards me throughout the period of this research work.

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ABSTRACT

The study was carried out on a floodplain formed by Otamiri river, Nkesi river and otamiri River, all in Southeastern Nigeria with the aim of determining and studying the Nitrogen Forms and fertility status of some selected soils of the area for optimal management and utilization. The Nitrogen forms are total nitrogen, total organic nitrogen and inorganic nitrogen which consist of Nitrate nitrogen (NO_3^- N), Ammonium nitrogen NH_4^+- N and Nitrite (NO_2^- N). The soils were derived from coastal plain sands and the corresponding sites were Emeabiam, Ohaji Egbema, and Oguta. Three pedons were dug in each location. A total of 42 soil samples were collected and subjected to routine analysis. Data generated was analyzed statistically using coefficient of variation. They had high sand fraction and clay content. The dominant hues were 5YR and 2YR in Emeabiam, 2Y and 5Y in Ohaji Egbema and 10YR in Oguta. Soil texture varied from sand to loamy sand. Bulk density had means of 1.48 gkg^{-3} to 1 68 gkg^{-3} at Emeabiam, 1.17 gkg^{-3} to 1.25 gkg^{-3} at Ohaji Egbema, 1.34 gkg^{-3} to 1.53 gkg^{-3} at Oguta, The pH (H_20) indicated that soils were moderately to slightly acidic with mean values of 5.55 to 6.32 at Emeabiam, 5.74 to 6.14 at Ohaji Egbema and 6.25 to 6.32 in Oguta. Organic carbon were low with mean values that ranged from 0.46% to 0.90 % at Emeabiam, 0.52 % to 0.95 % at Ohaji Egbema, 0.22 % to 0.90 % at Oguta. Organic matter content were low 0.79 % to 1.73 % at Emeabiam, 0.93 % to1.55 % at Ohaji Egbema, 0.36 % to 0.66 % at Oguta. Total Nitrogen content were low in all the pedons with mean values that ranged from 0.08gkg^{-1} to 0.13gkg^{-1} at Emeabiam, 0.09 gkg^{-1} to 0.10gkg^{-1} at Ohaji Egbema, 0.04gkg^{-1} to 0.08gkg^{-1} at Oguta. Available Phosphorous content were generally low with mean values that ranged from 3.46 mg/kg to 10.74 mg/kg at Emeabiam, 4.62 mg/kg to 6.80 mg/kg at Ohaji Egbema, 4.20mg/kg to 4.62mg/kg at Oguta. Effective Cation Exchange Capacity (ECEC)was low to moderate with mean values that ranged from1.06 cmol/kg to 1.68 cmol/kg at Emeabiam, 7.11cmol/kg to 8.83 cmol/kg at Ohaji Egbema, 3.66 cmol/kg to 4.90 cmol/kg at Oguta. Base saturation was high in all the pedons with mean values that ranged from 63.34% to 82.6% at Emeabiam, 74% to 83.6% at Ohaji Egbema, 89% to 93% at Oguta. There was positive correlation between organic carbon and all the nitrogen forms of Emeabiam. Sand correlated positively with TN (r= 0.54*), TON (r =0.51*) and NO_3-N (r =0.50*), Available Phosphorous and SCR correlated positively with all the nitrogen forms at Ohaji Egbema, TEA correlated with all the nitrogen forms for Oguta ECEC correlated with NH_4^+- N (r = 0.53*), NO_3^- N (r =0.52*), TIN (r = 0.53*). Total nitrogen, total organic nitrogen, NO_3^- N, NH_4^+- N had high mean values in all the locations studied except Nitrate nitrogen at Oguta location that had mean values that ranged from (11.24mg/kg to 17.82mg/kg). This result showed that the soils had low fertility and also needs adequate management for sustainable utilization. The nitrogen forms studied showed that total nitrogen was high in all the locations. Ammonium nitrogen was high with mean values that ranged from 56.7mg/kg to 89.4mg/kg and above the critical limit suitable for crop production. Nitrate nitrogen was moderate at Oguta soils with mean values that ranged from11.24 mg/kgto 17.82 mg/kg. Nitrate for OhajiEgbema was moderate in Pedon 1 with a mean of 17.44 mg/kg and high in pedon 2 mean 40.76 mg/kg and pedon 3 mean 53.06 mg/kg. nitrite was high with mean values that ranged from 13.58 to 21.40 mg/kg at Emeabiam, 8.02 to 20.92 mg/kg at Ohaji egbema and 7.13 to 7.76 mg/kg at Oguta. inorganic nitrogen was also high with mean values that ranged from97.33 to 149.3 mg/kg at Emeabiam, 55.86 to 127.38 mg/kg at Ohaji Egbema and 43.15 to 60. 52 mg/kg at Oguta.

Keywords: Nitrogen Forms, Floodplain, Pedons, Fertility, South Easthern Nigeria

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of Study

In Nigeria, agriculture is the main source of livelihood for most of its populace, especially those living in the rural areas and also a source of food and income for those who are engaged in the sector. With its fast growing population, there is now a need to intensify effort at meeting the increasing demand andsustainability of higher food requirements (Afu, Isong, and Awaogu, 2019). One of the ways to achieve this is through the expansion of available cropping land and utilization of floodplain Soils. In recent times, agricultural use of floodplain soils has increased significantly in Africa including Nigeria. (Ogban and Ibia, 1998; McCartney, Rebelo, Senaratna and Silvia 2010; Onyekwere,Akpan -Idiok, Amalu, Asawalam and Eze 2011; Ogban, Effiong, Obi and Ibia 2011, and Akpan – Idiok, 2013).

One major problem often associated with exploitation of such land use is the deficiency of nutrients especially nitrogen and as such their concentrations in soils are patient in the promotion of crop nutrition.Nitrogen occurs in both organic and inorganic forms in aquatic ecosystems.Globally, floodplains soils are useful for agricultural production as they constitute a huge reserve of available nutrients for utilization by crop plants. The Soils are also used for aquaculture (Sheriff, Arthur and Hong, 2008; Nagabhatal and Vanbrakel, 2010).Soils of floodplains have been characterized by moderate to high contents of basic cations, organic carbon, moderate to strong acidity and rated moderate to high in fertility status (Ogban and Babalola, 2009, Ogbaji, 2010, Hossain , Khan, Hussain, and Mazumder, 2011;

Ukabiala,2012).

There is inadequate information on profile distribution of different forms of nitrogen, under different ecosystem in Imo State. This calls for research rite to nitrogen forms and status and in the soils under different ecosystem in Imo State. Nitrogen plays a very significant role in plants. One of the key mineral elements required for animals and plants life sustenance is nitrogen. The forms of nitrogen determine it's rate of assimilation by plant and microbes. Nitrogen is assimilated when in an inorganic forms (Brady and Weil 2002, Uzoho,Ekpe, Ahukaemere, Ndukwu, Okoli, Osisi and Chris Emenyeonu,2014). Nitrogen entering the soil undergoes various changes, depending upon its form. Some Nitrogen processes are beneficial to plant nutrition while others are detrimental or harmful. Nitrogen can be converted to forms that are not available to plants, and can be converted to forms that are available to plants by soil bacteria. Nitrogen is the main limiting factor in crop production and soil management systems may change the mineralization and nitrification rates. It is required by all organisms for the basic process of life to make proteins, to grow and to reproduce (Sheila, 2007). Nitrogen is very common and found in many forms in the environment. Inorganic forms include nitrate (No_3), nitrite (No_2), ammonia (NH_3), and nitrogen gas (N_2). The ninety five persent of Nitrogen in the soil exists as insoluble organic matter (Jeff, Lynne, Mark, Nina, and Marta,2018). Soil nutrient dynamics in seasonal floodplain ecosystems are highly complex as a result of flood pulses and changing redoximorphic state. Flood pulse refers to the alternating dry and wet conditions in floodplain ecosystems. It facilitates soil nutrient exchange between rivers and their associated seasonal floodplains. During flooding soil nutrients dissolve in flood waters and are transported from seasonal floodplain surfaces into adjacent rivers. Soil nutrients may also be transported from the river into seasonal floodplains during dry periods. Soil flooding can cause hypoxia leading to a reduction in the soil nutrient content available to plants (Tsheboeng, Bonyongo, and Murray-

Huddson, 2014). Dissolved nitrogen in mangrove water consists of organic and inorganic nitrogen. The possible sources of dissolved inorganic nitrogen in mangrove ecosystem include river carrying runoff from agricultural fields, domestic sewage and effluents from aquaculture ponds, groundwater flux from mangrove and adjoin regions (Priya and Ramanthaan, 2017).

Plant development and biomass production depend on the availability of nutrients such as inorganic nitrogen in the soil. When considering the growth of trees, nitrogen is usually a limiting factor, thus nitrogen assimilation and metabolism by plants is important (Donald and Jackey 2013). Nitrate is the most common form of inorganic nitrogen in soil, being the final product of the decomposition of organic material under anaerobic conditions. It is the form normally taken up by plants (Powlson and Addiscott, 2005). Processes that reduce the rate of nitrogen presence in a soil include removal of harvested products, leaching of available nitrogen, denitrification of nitrate (prolonged period of wet soil, volatilization of ammonia). The intricacy of their habitat coupled with lack of scientific knowledge of most of the wetland soils in Nigeria have contributed to their underutilization. There is inadequate information on the nitrogen forms and fertility status of floodplain soils hence, this investigation which is aimed at ascertaining nitrogen forms and fertility status of floodplain soils in Imo StateSouth Eastern Nigeria.

1.2 Problem Statement

One of the major problems militating against the development of an economically successful agriculture is nutrient deficiency for crop production. Nitrogen is the main limiting factor in crop productivity. Soil management systems is capable of changingnitrogen mineralization and nitrification rates. Nitrogen undergoes complex transformation between its various forms by means of physical, chemical and biological process. However limited information is available on nitrogen forms in floodplain soils. The lack of information about flood plain soils may lead to poor recommendation on usage and this is a major obstacle to increasing agricultural productivity and food security. Thephysical and chemical properties of most floodplains are not well understood by farmers and this has led to limited usage, poor management and abandonment because of inadequate knowledge for agricultural production (Babalola, Oso, Fasina and Godonu 2011).

1.3 Justification of the Study

SeveralSoil Scientists have studied the soils in Imo State South-east Nigeria. This study thereforeis to show the nitrogen forms and fertility status of selected floodplain soils in Imo State southeast Nigeria.Nitrogen is necessary for our food supply but excess nitrogen can harm the environment. The delicate balance of substances that are important for maintaining life is an important area of research, and the balance of nitrogen in the environment is no exception (Weathers, Groffman, Dolah, Bernhardt, Grimm and Mcmahon, 2016). Understanding the properties of these soils as well as proper management is important for judicious, beneficial and optimal use on sustainable basis (Ojanuga,Okusami and Lekwa, 2003).

Nigeria faces fundamental challenges with regards to food scarcity as a result of ever increasing population and high demand on available food. The increasing importance of floodplain soils for food production and economic development and the need for sustainable development of agricultural sector makes this study useful. Agricultural potentials of floodplain soils are grossly under- utilized and have not been exploited fully mainly because of lack of understanding of them under intensive cultivation as they constitute a source of economic and agricultural values (Effiong and Ibia, 2009). Information needed of the nitrogen forms of many floodplain soils is inadequate. Therefore it is necessary that a complete inventory of floodplain soils be taken through medium and large scale resources surveys (Okusami and Rust, 1992; Akamigbo, 2001, Ojanuga *et al*., 2003). The limited available fertile upland soils that would have helped to boost crop productivity and yields have been used for non agricultural purposes such as urban infrastructure and or industrial uses. The increasing importance of floodplain soils for food production and economic development and the need for sustainable development of agricultural sector makes the study useful.

1.4 Objective of the Study

The major objective of this study was to investigate the nitrogen forms and fertility status of selected floodplain soils in Imo State Southeast Nigeria.

The specific objectives were:

i. To determine the physicochemical properties of soils of the study area.

ii. To determine the various forms of nitrogen in studied floodplain soil.

iii. To determine the functional relationship between the soil properties and nitrogen forms.

iv. To determine the fertility status of studied areas using elemental ratio.

1.5 Scope of the Study

The scope of this research was the major floodplain areas in Imo State located in Oguta, Owerri West and Ohaji Egbema Local Government Areas. It involves the evaluation of the nitrogen forms and fertility indices especially nutrient ratios. These three Local Government Areas are agrarian communities with large floodplain of agricultural potentials and yet not much is known about these soils with regard to nitrogen forms and fertility status of their soils. Physical, chemical properties of the soils and nitrogen forms were determined. Relationship among soil properties was determined also.

CHAPTER TWO

2.0 Literature Review

2.1 Soil

The soil is the basis for food production. The destruction of the surface soil constitutesone of the biggest ecological problems of the world and food scarcity (Stephen, Nort, Hurlkpe, Claus and Terytze, 2006). According to Garrison (2016), soil is the biologically active, porous medium that has developed in the uppermost layer of earth's crust. Soil is one of the principal substrata of life on earth, serving as a reservoir of water and nutrients, as a medium for the filtration and breakdown of hazardous wastes and a participant in the cycling of carbon and other elements through the global ecosystem. It has evolved through weathering processes driven by biological, climatic, geological and topographic influences. Soil differ widely in their properties because of geologic and climatic variation over distance and time.Soilis defined as the unconsolidated mineral or organic material on the immediate surface of the earth that serves as a natural medium for the growth of land plants. Also soil is the unconsolidated mineral or organic matter on the surface of the earth that has been subjected to and shows effects of genetic and environmental factors of climate including water and temperature effects and macro and microorganisms, conditioned by reliefs, acting on parent material over a period of time. Soil performs many critical functions in the ecosystem (whether a farm, forest, prairie, marsh, or suburban watershed).Soils modify the atmosphere by emitting and absorbing gases (carbon dioxide, methane, water vapour and dust). Soils process recycled nutrients including carbon so that living things can use them over and over again. Soils serve as media for growth of all kinds of plants. The soil environment is the most complex habitat on earth and provides a

range of habitats that support an enormous population of soil organisms. The nature of the habitat is determined by the intensity of the interaction of geology, climate and vegetation and is a biochemical product of the organisms participating in its genesis. Soils are among the great ecosystem service providers on earth (Haygarth and Rits, 2009). They store and provide water for plants, prevent floods by transferring water slowly to streams and ground water, and remediate pollutants. They cycle and recycle nutrients and wastes by transforming them into biologically available forms, storing them away for later use and preventing their leaching to ground and surface water. Soils are the host of small medium and large organisms that live in soil including mammals, birds, insects, and protozoa. Soil microbes (bacteria, fungi and archaea are the greatest biodiversity in the soil (Needelman, 2013). The major provider of nutrients and water for plant life and water for plant life on earth is the soil. Soils retain nutrients by several mechanisms. Soils also hold nutrients by retaining the soil water itself. Soils have a great capacity to filter and remediate pollutants. Soil even helps clean the surrounding air and water. They acts as a living filter to clean water before it moves into the aquifer. Soil absorb, hold, release, alter, and purify most of the water in terrestrial systems.

2.2 Soil Fertility

It is now clear that an indispensable sector of Nigeria economy (That is Agriculture) is facing serious constraints of scarcity of land and decline in soil fertility (Udo, Ibia, Ogunwale, Ano and Esu 2009). One of the biophysical constraints to increasing agricultural productivity is the low fertility of the soil (Bekunda, Batiano and Sali 1997). Soil fertility has declined in the farming regions of Africa. Artificial and natural fertilizers have been used to regain the nutrients of ground soil (Smaling, 1997). Also many countries in Africa undergo a depletion of fertile soil. In regions of dry climate like Sudan and the countries that make up the Sahara

Desert, droughts and soil degradation are common. Low soil fertility could be due to nutrient depletion, mining, soil acidification, loss of organic matter and increase in toxic elements (Hartemink, 2003).Depletion may occur through a variety of other effects; including over tillage which destroys soil structure, under use of nutrient inputs which leads to mining of the soil nutrient bank and salinization of soil. Soil fertility can be reduced or challenged when land use change rapidly. For example in the colonial New England, Colonist made a lot of decision that depleted the soil including allowing herd animals to wander freely, not replenishing soils with manure and a sequence of events that led to erosion (Coron and Williams, 1983). Land degradation and soil nutrient depletion have become serious threats to agricultural productivity in sub Saharan Africa. Most arable lands have been damaged by degradation thereby reducing agricultural productivity, which in turn results in poor economic growth of countries. Improving soil fertility levels has become an important issue in development agenda because of its linkage to food insecurity and economic wellbeing of the population

(Mitiku,1996).Sustainable agriculture practitioners and soil fertility practitioners know that most soils today need their vitality and health results. In the past vital soil and healthy soils were built by nature and there is value in copying nature in rebuilding soil health. However, nature takes longer and millions of years to do this hence we need intelligent intervention (Hugh, 2014). Examples of methods used include cultivation, composting, green manuring, soil conservation, soil testing, soil remineralization, fertilizer priorities and visual soil assessment all play a role in establishing self regenerative, self sufficient fertile soils. The Biological activities that take place during self regenerative soil fertility occur at the surfaces of soil particles where minerals come into contact with water, air and warmth. It is at these surfaces that biological activities provide nitrogen fixation. Rain forests are fertile ecosystems with rich diversity of microbial. Plant and animal species are nature's way of building soil fertility which involves awesome diversity, and intense cooperation. Every ecological niche is filled, all need is satisfied, and all gathered, recycled and conserved no area is left bare, and no opportunity is lost. Soil Fertility is the ability of soil to sustain agricultural plant growth that is to provide plant habitat and result in sustained and consistent yields of high quality. A fertile soil has ability to supply essential plant nutrients and water in adequate amounts and proportions for plant growth and reproduction. A fertile soil is devoid of toxic substances which may inhibit plant growth. In spite of the growing awareness of low cost of soil fertility technologies, the rate of adoptionand continued use of the technologies remain limited (Takele, Ahcdu, Alemayehu, and Abebaw, 2015). Farmers will adopt technologies that contribute positively to their livelihood. Hence, if soil fertility problems are viewed critical for their livelihood, farmers will definitely implementthe new technology. Decline in soil fertility causes low productivity and low agricultural production. Addition of fertilizer helps to increase agriculture production in order to meet the consumption needs of the growing population which was making extensive agriculture practice impossible. Soilproductivity is heavily depended on the fertility of the soil.

2.2.1Factors That Affects Soil Fertility

Mineral Composition: The mineral composition of the soil helps to predict the ability of the soil to retain plant nutrients trough the soils clay content, the cation exchange capacity (CEC) is determined. A higher CEC means more nutrients are present in the soil and low CEC shows the possibility of losing nutrients by leaching. Also soil’s natural fertility depends largely on the parent materials from which the soil has developed and the original vegetation. Soil pH: Soil pH helps in maintaining the nutrient availability of the soil. pH affects the nutrient availability in the soil. A pH range between 5.5 -7 is optimum for soil fertility. Soil pH affects the nutrient availability in the soil. Texture: The texture of different sizes is responsible for maintaining the structure of the soil. Different sized minerals sand, silt and clay. In comparison to sandy soils, clay soils are capable of retaining more nutrients and so act as a bigger nutrient reservoir. Cover crops in general are fast growing annual planting of grasses, legumes and herbaceous species intended to rebuild soil biology, restore nitrogen fixation or ploughing back into the soil. Organic Matter: Organic matter is a source of nitrogen and phosphorus. Soil organic matter plays a critical role in soil processes and is a key element of integrated soil fertility management, (Brady and Weil, 2004). Organic matter consists mainly of decayed or decaying plant and animal residues and is a very important soil component. According to Ashman and Puri (2002), Organic matter does the following to the soil: it holds and supply available plant nutrients (N, P and S). it increases the soils cation exchange capacity. Organic matter is food for soil organisms from bacteria to worms and is an important element in the nutrient and carbon cycles. Organic matter can also hold large amounts of water, which helps nutrients move from soil to plant roots (Mikkuta, 2004). Adding Manures and Fertilizers: The use of inorganic fertilizers as an option for improving soil fertility and productivity has immediate results but is unaffordable for most farmers (Takele et al. 2015). Fertilizers such as (NPK) Nitrogen, Potassium and Phosphorous are added to the soil to make it fertile and also they help to enhance plant growth. NPK and urea are the most common fertilizers required by the soil. Urea adds nitrogen to the soil. Erosion and severe run-off are depleting existing soil nutrient reserves, while levels of organic matter are declining as land is subject to over use. Inorganic fertilizer has immediate effects on crop production, therefore a good option for improving soil fertility. Inorganic fertilizers and other amendment are used to maintain the fertility of the soil. Manure is an important input for maintaining and enhancing soil fertility. The use of animal dung, ash and household trash to crop land is common practice to improve soil fertility. Leguminous Crops: Leguminous plants are plants containing nitrogen-fixing bacteria such as Rhizobium in the most noodles. These bacteria trap atmospheric nitrogen and make it available to the plants in the form of nitrogen compounds. The remaining nitrogen compound are mixed with the soil to increase its fertility.

Bulk Density: Soil fertility also depends on its bulk density. The soil should not be compacted for easy penetration of the roots.

Moisture Content: The amount of moisture that resides in the soil can also influence soil fertility. Actual nutrients can be found in the soil solution and not the solid matrix. It is more desirable to use soil with higher moisture content to increase and ensure its fertility. Soil with low moisture content are not very fertile. Soil water: Water in soil pores carries the nutrients to plant roots.

Land Use: Land use changes from mixed farms where crop rotation with legume pastures was common to continuous cereal cropping generally resulted in a decline of crop residue based nitrogen mineralization (Angus, Bolga, Kirkegaard and peoples, 2006). The decline occurred mainly through altered crop residue qualifying cereal residues replacing nitrogen rich legume residues

2.3 Concept of Floodplain

Floodplain is an area of land adjacent to a stream or rivers which stretches from the banks of its channel to the base of the enclosing valley walls, and which experienced flooding during periods of high discharge (Goudie, 2004). Floodplains are areas bordering or adjacent to the course of the rivers or streams. Generally they have low gradient and are liable to seasonal flooding during the rainy season. Floodplains lowlands that are periodically inundated during normal flood aid in the mitigation of flood.Research has found out that about 12 million hectares of floodplain have been put into agriculture in Africa. In West Africa, about 47% of floodplain soils have been put to rice cultivation, while about 65,783 hectares of floodplains constituting about 7.2% of total land area have been identified in Nigeria (Wakatsuki, 2004). Floodplain is the natural place for a river to dissipate its energy. Natural floodplains are among the most biologically productive and diverse ecosystems on earth. The fine and coarse materials (sediments) carried by flood water are deposited in the floodplains.

2.3.1 Floodplain Soils

According to Van Breeman (1980), floodplain soil can be defined as soils that are pounded or water saturated during most of the time that they are used for food production because most of them are seasonally flooded. It is associated with a low lying topography. The soils are found on alluvial deposits of the floodplains of major rivers. Nigeria flood plain soils are unknown, underdeveloped and underutilized (Ojanuga *et al*., 1996).Flood plains soils usually consist of levees, Silts and Sands deposited during floods. Levees are the heaviest materials usually pebble size and they are deposited first, silts and sands are fine particles. Floodplain soils have great agricultural potentials and should be utilized for crop production (Akpan- Idiok and Ogbaji, 2013). Floodplain soils are distributed along major active rivers in West Africa, about 47% of the soils have been utilized for rice cultivation (Wakatsuki, 2004). Studies also state that seasonal submergence and drying are the most active factors in developing redoximorphic features such as mottles, iron and manganese concretions, chroma diagnosis of 2 or less, gleyed soil matrix (Egbuchua and Ojobor, 2011; Hossain, Khan,. Hussain,. and Mazumber, 2011). Flood plain soils have been characterized by moderate to high contents of basic cations, organic carbon, \ moderate to strong acidity and rated moderate to high in fertility status (Ukabiala, 2012).Worldwide, floodplain soils are useful for agricultural production as they constitute a huge reserve of available nutrients for utilization by crop plants. The soils are also used for aquaculture (Nagabhatla and Van, 2010). Physico chemical and mineralogical properties of floodplain soils have shown from studies that they soils are essential for sustainability classification of the soils for crop production (Ayalew and Beyene, 2012). The soils formed on this floodplains differ in their morphological, physical and chemical characteristics probably due to its age of sedimentation, micro relief, drainage and mineralogy (Hossain, Khan, Hussain and Mazumder 2011).

The origin or genesis of floodplains soil-(hydromorphic soil) in Nigeria has been attributed to three major land forms type which include alluvial plains, coastal plains and inland depressions. Alluvial plains consist of floodplains, levees, back swamps and terraces. Coastal plains have deltas and swamps. Inland depressions consist of inland basins and inland valleys (Okusami and Rust, 1994). Floodplain soils are of immense value to the global community because of the fragile ecosystem with high agricultural potentials (Nsor and Akamigbo, 2009). Currently, there is wide spread decline in the fields of most upland crops in already existing agricultural lands. This decline is primarily due to depletion of soil nutrients as a result of continuous cultivation (Yebo, 2015), and soil degradation (Yusuf and Yusuf, 2008). The few available fertile upland soils that would have helped to boost crop productivity and yields have been used for non agricultural purposes such as urban infrastructural or industrial uses. Thus making upland soils for agriculture a scarce resources (Aki and Isong, 2018). This could be the reason why Nigeria was among countries that were affected with the last global food crisis (Oparaeke, Ofor and Ibeawuchi, 2010), and has recently been enlisted as one of the poorest countries in the world. Therefore, it is necessary that pragmatic steps be taken to save Nigeria from an impending danger of more serious food crisis in the near future. However, the problems related to land scarcity or declining productivity from upland agriculture could be alleviated through expansion of available cropping land into flood plain soils. Flood plain soil is an area of land adjacent to a stream or rive which stretches from the banks of its channel to the base of the enclosing valley, walk and which experiences flooding during periods of high discharge (Gouldie, 2004). The features of the flood plain varied widely in accordance with the multiplicity and diversity of ecologies with which they are associated (Eshett, 1994). Floodplains are usually fertile flat and easily farmed. In most of the developed world, floodplains are widely farmed and cleared of vegetations. Farmers go to flooded areas for their activities because they are usually very fertile for farming, there is availability of water and nutrients for crop growth in these areas. But in developing world, floodplains are largely ignored because the agronomic task on the soils are more strenuous and tedious than on upland soils (Eshett, 1990). Floodplains characteristics and potentials are little understood (Ogban and Babalola, 2003). Floodplains soil is the nature's free gift could mitigate the problem of water availability, and if properly utilized could sustain long growing season crops (Juo and Hossner, 1992) compared to upland soils. Worldwide, floodplains soils are useful for agricultural production as they constitute a huge reserve of available nutrients for utilization by crops (Akpan-Idiok and Ogbaji, 2013). Floodplain soils mostly consist of levees, silts and sand deposited during floods. In recent times, agricultural use of floodplain soils has increased majorly in developing countries particularly in Africa including Nigeria. (Akpan-Idiok, Ukabiala, and Amhakhiani, 2013). Floodplain soils are distributed along major active rivers in west Africa, about 47% of the soils have been utilized for rice cultivation (Wakatsuki, 2004). In Nigeria, about 65,783 ha of floodplains constituting about 7.2% of the total land areas have been identified (Ojanuga, Okusami, and Lekwa, 2003). Characterizing the floodplain soils for agricultural purposes does not only establish relationship between soil properties and the landscape parameters, but also provide preliminary information on the nutrient status, limitation and ensure sound judgment on the behavior or response of the soils to specific uses (Egbuchua and Ojobor, 2011).

2.3.2 PropertiesandCharacteristics of Floodplain Soils

Studies have shown that seasonal submergence and drying are the most active factors in developing redoximorphic features such as; mottles, iron and manganese concretions, chroma diagnosis of 2 or less, gleyed soil matrix (Ogban and Babalola, 2009; Egbuchua and Ojobor, 2011, Hossain *et al,* 2011). They are characterized by significant humus accumulation, grainy structure, development of gley in the lower horizons and new hydrogenic formulations (for example, ferromagnesium). They are distinguished by silting and bog formation. Generally they have low gradient and are liable to seasonal flooding during the rainy season. A floodplain is distinguished by the presence of a large number of organisms, stratification and the existence of buried humus horizons. The soil usually consists of leaves, silts and sands deposited during floods. Floodplains are perhaps the most common of fluvial features in that they are usually found along every major river and in the most large tributary valleys. Topographically, floodplains are relatively flat surface that stand adjacent to river channels and occupy much if the area constituting valley bottoms. A floodplain has a significant hydrologic role. A floodplain is so intimately related to flood, it can be defined in terms of the water level attained during some particular flow condition of a river. Floodplain soils form the back bone of arable crop production in the semi arid and arid Savannah agro-ecological zones where precipitatation (rainfall) is for agricultural productivity. Floodplains are predominantly flat floored inland valleys bordering or adjacent to the banks of major rivers and streams. The form part of a larger group called the wetland soils (Akamigbo, 2001). Floodplains are known as Fadamas in northern Nigeria because of their use in intense agricultural production. Fadama soils mainly have low gradient and are liable to seasonal flooding at the peak of rainy season. (Ogbaji, 2010). The terrain features of most West African floodplains comprises of levees, back swamps, sandbar and ox-bow lake (Fagbami & Vega, 1995). Floodplain soils are among the most fertile on earth due to recurring flooding that deposits nutrient rich fine grained sediments. Floodplain soils usually consist of levees, silts and sands deposited during floods. Levees are the heaviest materials (usually pebble – size) and they are deposited first, silts and sands are finer materials. Wetting of the floodplain soil releases an immediate surge of nutrients: those left over from the last flood, and those that result from the rapid decomposition of organic matter that has accumulated since then. Microscopic organisms thrive and larger species enter a rapid breeding cycle. Floodplain soils are found along rivers, lakes, lagoons and or depressions on adjacent low terraces where they develop in sediment from various sources under various drainage classes often with hydromorphic conditions (Akamigbo 2001, Ojanuga *et al*, 2003,). Floodplain soils are used for agriculture because of their natural fertility and these soils are known for their high organic carbon, total nitrogen and cation exchange (CEC) (Ekwoanya and Ojanuga, 2002). Floodplain soils are productive as a result of frequent saturation and duration of flooding that brings in nutrient rich sediments, from surrounding watersheds (Mitsch and Grosselink, 2000). Despite these properties to support fields of arable crops the physical and chemical properties of most floodplains are not well understood by farmers and this has led to limited usage, poor management and abandonment because of inadequate knowledge for agricultural production (Ano, 2000). The knowledge of floodplain soils is critical for decision making with respect to crop production and other land uses. Flooding is a natural process that replenishes soil and nutrients to floodplains. Floodplains are ideal sites for agriculture. They are flat, water is accessible.

The wetlands in tropical sub-Sahara Africa, that is, the warm zone with a growing period of 150 days or more (FAO, 1978) are usually classified as follows:-

i. Coastal floodplains, including deltas, estuaries and tidal flats.
ii. River floodplains which are recent alluvial deposits bordering rivers.
iii. Inland basins, comprising extensive drainage depressions.
iv. Inland valleys, flat-floored relatively shallow valleys.

The wetness of the land could be attributed to natural flooding of the land, high water table or ponding.

2.3.3 Geology and Genesis of Floodplain

Floodplains are formed when a meander erodes sideways as it travels downstream. When a river breaks its banks, it leaves behind layers of alluvium (Silt). These gradually build up to create the floor of the plain. Floodplains generally contain unconsolidated sediments, often extending below the bed of the stream. The sediments are accumulations of sand, gravel, loam, silt and or clay and are often important aquifers, the water drawn from them being pre-filtered compared to the water in the river. Geologically, ancient floodplains are often represented in the landscape by fluvial terraces. These are old floodplains that remain relatively high above the present floodplain and indicate former courses of streams. Formation of floodplain is marked by meandering or anastomotic streams, oxbow lakes and bayous, marshes or stagnant pools, and is occasionally completely covered with water. Floodplains differ because they are altogether flat. They have gentle slope downstream and often for a distance, from the side towards the centre. Floodplain soils are formed on the alluvial deposits of the floodplains of major rivers. Sediment or alluvium of floodplains coarseness and composition varies as it depends on surrounding landscape and the velocity of the currents that created the floodplains. Most floodplain soils are sandy while others are fine grained (Akamigbo, 2001, and Onweremadu, Ndukwu, Opara and Onyi, 2007). One of the most important geologic features of floodplain soils is the formation of fluvial terrace (step-shaped areas of the land that flank the bank of a river or stream). Fluvial terraces mask the older, higher elevation paths of the stream, before erosion and degradation created the current main stream of the stream or river (Ojanuga *et al*; 2003). Fluvial terraces are of two types: fill and cut terraces. Fill terraces are formed as a result of valley or gorge filled with alluvial, while Cut terraces is as a result of erosion and are often formed below Fill terraces, when water erodes sediments. Climate and organism actively influence the process of soil formation, while relief indirectly affects the rate of formation and distribution of soil nutrient (Onweremadu and Mbah, 2009). The formation of fluvial terraces step shaped areas of land that flank the bank of a river or stream is an important geologic feature of floodplain soils. Fluvial terraces mark the older, higher elevation paths of the stream, before erosion and aggradations created the current mainstream of the stream or river (Ojanuga *et al;* 2003). A meander stream contributes to floodplain soils aggradations or built up as well as its erosion for example in a wide shallow braided rivers example of braided river include river deltas, where the main floodway is separated into discrete channels and tinny Islands and through the process of subsidence as the delta sinks as a result of human activities or sea rise forming aggradations of sediments as can be seen around the Nile , delta, which subsides due to the sea rise in Mediterran sea (Ojanuga *et al* 2003; Onweremadu *et al* 2007) . Oxbow lakes and seasonal wetlands features are sometimes part of floodplains soils created by the process of erosion and deposition (Okusami and Rust, 1992, Brady and Weil, 2002). Alluvial floodplain deposits are derived from the basement complex through the rivers flowing across the geology, the soils formed usually contain moderate amount of exchangeable bases (Ca, Mg, k, and Na); while those derived from alluvium originating from the sedimentary areas have low amount of exchangeable bases (Ojanuga 1984, Onwerenmadu *et al;* 2007). Floodplains are unique ecosystem with landscape positions where the presence and actions of water creates unique landforms and soil properties. They are fragile ecosystems and their indiscriminate use can result in severe ecological and environmental deterioration and degradation (Babalola, Oso, Fasina, and kodonu, 2011). Floodplains vary in nature, some are narrow others are very wide depending on the size of river; some are extraordinary wide. Some floodplains in Nigeria include Benue floodplains streching to Gongola, Niger river floodplains extending from Kenji Dam, Lokoja to lower floodplains in Onitsha. Floodplains can support particularly rich ecosystems, both in quantity and diversity. Floodplains are a category of riparian zones or systems. Floodplains are valuable for agriculture. Nigeria is endowed with surface and underground water reserves which are rich nutrients from the alluvial deposits of pastures arable crops and fish farms (Onyekwere, *et al.,* 2011). Floodplains have been under serious pressure as a result of population increase and cultivation on the fragile areas, soils erosion, decline in soil fertility of arable lands and insufficient food for the area increasing population in the world (FAO and IITA 1999)

2.3.4 Morphological Properties of Floodplain Soils

Soil Morphology deals with the form, structure and organization of the soil material observed, described and studied in the field (Balasubramanian, 2017). Morphology also is defined as the field observable attributes of the soil within the various soil horizons and the description of the kind and arrangement of the horizons (Esu, 2010). The observations are typically performed on a soil profile. The morphological properties include colour, texture, consistence, boundary form, roots, drainage etc. The first and most observable physical parameter that is observed about any soil is the color. Soil Survey Staff (2003) the three attributes used mainly in describing soil are hue (major colour, reddish or yellowish), chroma (brightness or intensity) and value (constrast). Soil colour shows a combination of physical, biological and chemical changes in the soil. It is a very important attribute used in morphology for interpretation and classification of soil (Esu 2010). Soil colour varies from top soil to sub soil. The colour of top soil normally shows the biological processes mainly influenced by the ecological origin of soil organic matter (SOM). It helps in recognizing the successions of soil horizons or layers in soil profiles. Colour is a function of pH, redox Reaction and organic matter. (Wakene, 2001). One major morphological feature such as gray or low chroma (<3) colour, mottles is a major feature and indicates soil wetness as a result of redox (oxidation-reduction) cycle due to fluctuation in the ground water. Gray colours are associated with saturated and chemically reducing soil environment, while yellowish brown coloured soils with high water increase and below (Flectcher and Veneman, 2005). Gleying: flooded soils will develop black grey bluish, or greenish colour as a result of the reduction of iron. Oxidized manganese is black, oxidized iron is reddish. When reduced they become colourless and can be leached out leaving the natural

grey or black colour of the parent material. Mottles and concretions: Wetted and dried soils develop spots of highly oxidized materials. They are reddish – brown and relatively insoluble, enabling them to remain in the soil long after it has been drained. The reduced iron (Fe^{++}) in these soils impact greyish colour on the soil matrix (Onweremadu *et al;* 2007; Babalola *et al*; 2011). The soils are sandy in nature. The soil contains mottles. Plant roots give evidence of plant root activity and the depth of penetration as well as presence of iron pan down the profile.

2.3.5Physical Properties of Floodplain Soil

Physical Properties: the physical properties of the soil profoundly influence how soil can be managed (Brady and Weil 2008). Soil physical properties dictates how soil function in an ecosystem, success or failure of both agriculture and engineering projects. Physical properties of soil include texture, structure, porosity, bulk density etc.

Texture: it deals with the fines or coarseness of the mineral particles. Soil texture indicates the general nature of soil physical properties which is considered very important in soil management and characterization (Isirimah, Igwe and Ogbonna 2006). Soil texture can be assessed in the field by fee method or laboratory by mechanical analysis. Soil textural class is determined using the textural triangle. Most of the physical characteristics of soil depend upon textural class (Mustafa, Sighn, Sahoo, Nayan, Khann, Sarangi and Mishra,2011). Soil textural class varied with positions of soils in the landscape where coarser materials were found in the upper slope positions and finer materials in the lower part of the slope position (Mohammed, *et al* 2005). The texture of these soils are dominated by high sand content, low silt retain has been attributed to high weathering intensity and leaching (Eshett, 1993; Onweremadu *et al;* 2007).

Soil Structure: soil structure is the product of processes that aggregate, cement, compact or consolidate soil materials. Structure modifies of texture in regard to moisture and air

relationship, availability of plant nutrients, action of microorganisms and root growth. Soil aggregate distribution and stability measurement have been proposed as soil quality (Marraccinini, Debolin, D-Bene, Bonari, andRapey,2012). Soil Structural property variations could be related to organic matter content and textural characteristics (Mohammed, Leroux, Barker, and Gebrekidan, 2005). The arrangement and placement of soil particle into aggregates determines the response of soil to exogenous stress such as tillage, traffic and raindrop impact

(Lal and Shuka, 2004). Porosity: A close inspection of the soil *reveals* that it contains solid minerals, water and space between the solid particles called pore space containing air (Isirimah, Dickson and Igwe, 2003). In general the finer the soil texture the greater the surface area and the total pore space (50-60%) and sands, the lowest (20-30%) , while loams are in between 30% (Donahue, Miller, and Schikluna, 1990). Organic soils have high porosity compare to mineral soils – about 80 -100% to 30%-50% respectively (Ojanuga *et al* 2003).

2.3.6 Chemical Properties of Floodplain Soil:

Soil pH:- Also known as soil reaction is the acidity or alkalinity of the soil. The first factor to be considered in soil fertility evaluation is soil pH (Shimeles, Lulseged, and Paul, 2012). Plants and soil organisms prefer pH range between 6.0 and 7.5 (Hazelton and Murphy, 2007). Soil pH indicates the state of weathering of a given soil. The pH of a soil may be acidic (pH<7) neutral (pH=7) or alkaline (pH>7). Soil pH strongly influences the soil biological system (microbial activities and nutrient availability). Plants cannot make use of N,P and K and other nutrients they want if the soil solution is too acidic (Spector, 2001). Soil pH is a measure of the concentrates of H^+ was in the soil solution or in other a measure of acidity or alkalinity of a soil. Cation Exchange Capacity CEC: is the capacity of a soil colloid to hold cations. it is the amount of nutrients that the organic compounds and clay could carry and make available to plant. The CEC of a soil is the quality of cations that can be needed or exchange by a given soil. It is measured in terms of centimole per kg (Cmol/kg). Cation exchange capacity is the main factor in measuring soil fertility which affects exchange of ions on the clay surface (Taye and Yifru, 2010). The non acid cations (Ca^{2+}, Mg^{2+}, K^+& Na^+) have been referred to as base cations and their proportion on the CEC called the percentage base saturation (PBS). CEC depends on the nature & amount of colloidal particles (Brady & Weil, 2008). Soils of virgin and or grazing lands and areas under long year of fallow practices and vertisol retain more basic cations, which are mainly dominated by exchangeable Ca and Mg (Tamirat, 1992; Mesfin, 1998; Eylachew, 2000). Fine textured floodplain soils are usually rich in organic carbon and hence CEC values are often high while coarse textured have been found to have low organic carbon due to high leaching and rate of decomposition (Igwe, Akamigbo, and Mbagwu, 2002, Ojanuga *et al;* 2003).Soil Organic Carbon: Soil organic carbon plays an Important role in nutrient cycle and in the soil ecosystem. In floodplain soils organic carbon varies with high values obtained in Organic Soils. In mineral soils values range from low to moderate, and high in top soils (Igwe *et al*., 2002).

2.3.7 Potentials and Uses of Floodplain Soils

The uses, potentials of floodplain soils are diversified. Floodplain soils are used for agricultural purposes. Floodplains soils are seasonally flooded but have all year round water supply as they stored water in the soil to make them suitable for permanent agriculture. Their potential for agriculture is great under appropriate management including drainage, flood control and fertilization (Ojanuga *et al;* 2003). Most of the wetland in sub-Sahara Africa are under-utilized. Many of them, including deltas, floodplains, forested regions, small wetlands and inland valleys have not been adequately or extensively cultivated. However, the present uses of such lands include:- Traditional gathering of forest products such as oil palm, raffia palm, medical plants, firewood and building materials. Yam-based cropping: the yams are often grown in large mounds or heaps made during the dry seasons. Dry season vegetable production: short season crops are produced from these lands during the dry season. Such crops include tomatoes, onions, peppers and other vegetables. Rain-fed lowland rice: This is quite common. We may have phreatic Riceland where there is high ground water table but no flooding or fluxial or flooded rice lands where the land is naturally or artificially flooded. Mangrove rice cultivation: This was introduced into West Africa particularly in Sierra Leone and Senegal, but not yet practiced in Nigeria. Hence the mangrove swamp, of which a good part has not been utilized for agricultural production in Nigeria. Biodiversity of floodplains soils: it is known that floodplains contribute significantly to the biodiversity of the world because so many species occur solely in floodplains or at least rely heavily on floodplains to satisfy important ecological needs. Floodplain forest soils are inhabited by 70 species of micromycetes, 53 genera of Nematode, 60 species of collembolan, and 110 species of large invertebrates. (Alla , Laptera, Degtera, Taskaera, Kudrin, Vinogradora and Khabibuilina, 2016). Floodplains soils are potential tree source and soil carbon storage: Floodplains soils have deep carbon storage. Floodplain forest are extremely productive for agriculture and historical. Floodplains soils are a potential phosphorus source. Floodplain forest ecosystems are key habitats for rare invertebrates, including the representatives of post glacial period. Riverine floodplains have also served as focal points for urban development and exploration of their natural functions. Floodplains are of great cultural and economic importance, Recreational and aesthetic values. The need for increase of more cultivable lands as a result of land use pressure on uplands and the quest for an increase in food production requires management of flood plain soils in

Nigeria (Ojanuga *et al;* 2003). Floodplain soils are used for agriculture because of their natural fertility and these soils are known for their high organic carbon, total nitrogen and cation exchange capacity (CEC) (Ekwoanya and Ojanuga, 2002). The effect of poor management of soil can result to severe ecological and environmental deterioration and massive degradation (Ahukaemere, and Akpan, 2012). The global food system is in serious crisis, as the soils of the uplands are been intensively utilized for all purposes at the expense of their suitability causing continuous degradation in their properties (Senjobi and Ogunkunle, 2011). Food scarcity as a result of increasing population and high demand on available food is one of the fundamental challenges facing Nigeria. Floodplain soils are productive as a result of frequent inundation and duration of flooding that brings in nutrient rich sediments from surrounding watersheds.(Mitsch and Gosselink, 2000). There is scarcity of available uplands, and the few available cultivated soils have become severely degraded by the continuous cropping practice by farmers. The vegetation of floodplains plays a major role in reducing the speed of flood waters and erosive forces and captures nutrient sediments to the surrounding soils. (Ojanuga *et al;* 2003). The ecosystem of floodplains are unique with landscape positions where the presence and actions of water creates unique landforms and soil properties. Floodplains have fragile ecosystems and their indiscriminate use can result in severe environmental and ecological degradation and deterioration.

2.4Nitrogen

Nitrogen is the seventh most abundant element in the universe (James, 2013). Nitrogen is one of the most important nutrients critical for the survival of all living organisms. It is a necessary component of many biomolecules, including proteins, DNA, and chlorophyll. Even though nitrogen is very important and abundant in the atmosphere as dinitrogen gas (N_2), it is very largely inaccessible in this form to most organisms, making nitrogen a scarce resource and often limiting primary productivity in many ecosystems (Bernhard, 2010). It is the key component in plant proteins and chlorophyll (Tom, 2002), and motor of plant growth (IFA 2000). The presence of nitrogen in plants is to enhance the vegetative growth and chloroplast formation for photosynthesis (Keller, 2005). Nitrogen occurs as both organic and inorganic nitrogen in aquatic ecosystems. Human activities such as fossil fuel combustion, use of artificial nitrogen fertilizers, and release of nitrogen in wastewater have dramatically altered the global nitrogen cycle

(Kuypers, Marchant and Kartal, 2011). The total nitrogen content depends largely on the soil organic matter content, which in turn depends on texture, climate, vegetation, topography, age and soil management for instance Soil under no –tillage maintain more soil nitrogen than tilled soil.

Nitrogen status of soils provides information about the capacity of soils to sustain crop productivity and maintain environmental safety (Uzoho *et al*; 2014). Nitrogen determines the sustainability of plant vegetative growth. There are biochemical processes especially those related to N Mineralization, and immobilization, soil organic and inorganic N fractions that could be transformed form one form to another (Fan, Hao, and Malhi, 2010). Organic Nitrogen as widely known to consist of nucleic acids, amino acids, proteins and amino sugars, while inorganic Nitrogen include ammonium and Nitrate nitrogen. The total Nitrogen stock of soil under natural conditions is influenced by climatic factors and vegetation. The major amount of total nitrogen in the soil is in its organic form which makes soil organic matter a very important reservoir of available forms of nitrogen for plants mainly in the forms of nitrate ($N0_3$-N) and ammonia (NH_3 –N) (D'Andrea, Silvia, Curi, and Guilhereme, 2004). Increasing levels of nitrogen deposition are shown to have a number of negative effects on both terrestrial and aquatic ecosystems.(Bobbink, Hicks, Galloway, Spranger, Alkemade and Ashmore, 2010). Soil nitrogen is directly related to the organic matter content and with high total nitrogen content on surface soils due to high organic matter accumulation (Moges, Dagmachew, and Yimer, 2013, Gebrelibanos and Assen, 2013). Variation in Nitrogen distribution among horizons of soil profile pits have been widely reported by (Zhijing , Xi, and An, 2013). Uzoho, *et al* (2014) stated that ammonium nitrogen is usually fixed by clay minerals with availability often low in soils high in clay contents. Further studies have shown that nitrate was the dominant form of Nitrogen produced on mineralization of pasture in all soil layers where as under forest land nitrate declined down the profile (Ahukaemere, Akamigbo, Onweremadu, Ndukwu and Osisi, 2015). Afforestation increases soil nitrogen accumulation and modifies nitrogen availability for micro organisms growth (Deng, Cheng, Yang, Zhang, and Luo, 2014), Thereby potentially influencing elemental cycles in terrestrial ecosystems (Li, Zhou, Zhang and Cheng, 2014). Soil nitrogen responds to changes in soil organic matter inputs, which can then impact Microbial processes. Soil N components would play an important role in Nitrogen cycling. Nitrogen is required by all organisms for the basic processes of life to make proteins, to grow and to reproduce (Murphy, 2007). Nitrogen is very common and found in many forms in the environment. Nitrogen is most abundant in earth's environment as N_2 gas, which makes up about 78 percent of the air we breathe. Nitrogen is an essential nutrient for plant growth and development but is unavailable in its most prevalent form as atmospheric nitrogen. Plants instead depend upon combined or fixed forms of nitrogen such as ammonia and nitrate. Much of the nitrogen is provided to cropping systems in the form of industrially produced fertilizers. Useof these fertilizers has led to worldwide, ecological problems, such as the formation of coastal dead zones – Biological nitrogen fixation, on the other hand, offers a natural means of providing nitrogen for plants. It is a critical component of many aquatic, as well as terrestrial ecosystems across our biosphere (Wagner, 2011). Nitrogen is a critical limiting element for plant growth and production. It is a major component of chlorophyll, the most important pigment needed for photosynthesis, as well as amino acids, the key building blocks of proteins. Nitrogen plays a key role in plant growth. Too little nitrogen and plants cannot thrive, leading to low crop yields, but too much nitrogen can be toxic to plants (Britto and Kronzuker, 2002). Environmental and economic issues combined have increased the need to better understand the role and fate of nitrogen (N) in crop production systems. However, when nitrogen inputs to the soil system exceed crop needs, there is a possibility that excessive amount of nitrate (NO_3) may enter ground or surface water. According to Leary *et al;* (2002) managing nitrogen inputs to achieve a balance between profitable crop production and environmentally tolerable levels of NO_3 in water supplies should be every growers goal. Nitrogen is found in soils and plants, in the water we drink, and in the air we breathe. It is also essential to life. It is essential to plant, and therefore necessary for the food we grow. Plants that lack nitrogen become yellowish in colour and stunted with smaller flower and fruits. Farmers also add nitrogen fertilizer to produce better crops but too much can hurt plants and animals and pollute our aquatic systems. Understanding the nitrogen cycle – how nitrogen moves from the atmosphere to earth, through soils and back to the atmosphere is an endless cycle can help us grow healthy crops and protect our environment (Aczel, 2019). According to Brady and Weil (2010), nitrogen is a key element in the nucleic acids DNA and RNA, which are the most important of all biological, molecules and crucial for all living things. DNA carries the genetic information which means the instructions for how to make up a life form. When plants do not get enough nitrogen, they are unable to produce amino acids (substances that contain nitrogen and hydrogen and make up many of living cells, muscles and tissue). Without amino acids, plants cannot make the special protein that the plant cells need to grow. Without enough nitrogen, plant growth is affected negatively. When much nitrogen plants produce excess biomass, or organic matter, such as stalks and leaves, but not enough root structure. In extreme cases, plants with very high levels of nitrogen absorbed from soils can poison farm animals that eat them. The building up of excess nitrogen leads to a process known as eutrophication. Excess nitrogen can also leach or drain from the soil into underground water sources, or it can enter aquatic systems as above ground runoff. Eutrophication happens when too much nitrogen enriches the water; causing excessive growth of plants and algae. Excessive nitrogen can even cause a lake to turn bright green or other colors with a bloom of smelly algae called phytoplankton. When phytoplankton dies microbes in the water decompose them. The process of decomposition reduces the amount of dissolved oxygen to support most life forms. Organisms in the dead zone die from lack of oxygen. These zones can happen in freshwater lakes and also in coastal environments where rivers full of nutrients from agricultural runoff fertilizer overflow flow into oceans (Foth, 1990).

2.4.1 Stages in Nitrogen Cycle.

Plants and animals recycle nitrogen always. The route that nitrogen flows in and out of the soil system is collectively called the "Nitrogen Cycle" and is biologically influenced. This recycling of nitrogen through the environment is called the Nitrogen Cycle. Nitrogen cycle is a repeating cycle of processes during which nitrogen moves through both living and non living things: the atmosphere, soil, water, plants, animals and bacteria (Aczel, 2019). Nitrogen cycle is the biochemical cycle by which nitrogen is converted into multiple chemical forms as it circulates among ecosystems. The conversion of nitrogen can be carried out through both biological and physical processes. Nitrogen can be provided for plant growth from several sources such as fixation. Nitrogen fixation is the bacterial process whereby molecular N_2 gas is converted to reactive, biologically available forms of nitrogen (Mario & Howorth, 2009). The conversion of nitrogen gas (N_2) into nitrites and nitrates though atmospheric, industrial and biological processes is called nitrogen fixation. Today about 30% of the total fixed nitrogen is produced industrially using the Haber-Bosch process (Smith, Richards, and Newton, 2004) which uses high temperatures and pressures to convert nitrogen gas and a hydrogen source (natural gas or petroleum. Atmospheric Fixation: Atmospheric Nitrogen is the major reservoir for nitrogen in the nitrogen cycle, air is (79% N gas). Atmospheric nitrogen is unavailable to most plants. Large amount of nitrogen can be used by leguminous plants through Nitrogen fixation. Nitrogen is fixed by natural ecosystems (Vitousek, Meng, Reed, and Cleveland, 2013). Biological Fixation: In this process, nodule forming Rhizobium bacteria inhabit the roots of leguminous plants and through a symbiotic relationship convert atmospheric nitrogen to a form the plant can use. Any portion of a legume crop, that is left after harvest, including roots and nodules supplies nitrogen to the soil system. When the plant material is decomposed, Nitrogen is released. Nitrogen cab be fixed by agricultural crops (Fowler, David, Coyle, Mhairi, Ute, and Sutton…2013). Microorganisms that fix nitrogen require 16 moles of adenosine triphosphate (ATP) to reduce each mole of nitrogen (Hubbell and Kidder, 2009). Some nitrogen fixation occurs by free living heterotrophs. Many heterotrophic bacteria live in the soil and fix significant levels of nitrogen without the direct interaction with other organisms. Examples of this type of nitrogen fixing bacteria include species of Azotobacter, Bacillus Clostridium, and Webisella. Symbiotic Nitrogen Fixation: Many microorganisms fix nitrogen symbiotically by partnering with a host plant. The plants provide sugars from photosynthesis that are utilized by the nitrogen fixing microorganisms for the energy they need for nitrogen fixation. Example of this type of nitrogen fixation is water fern Azolla's symbiosis with a cyanobacterium, Anabaena azollae. Other Important nitrogen, fixing symbiotic associations are the relationships between legumes and Rhizobium and

Bradyrhizobium bacteria. Important legumes in agricultural system include alfalfa, beans, clover, cowpea, lupines, peanut, soybean and vetches. Of all the legumes in agricultural production, soybeans are grown on 50% of the global area devoted to legumes and resent 68% of the total global legume production (Vance, 2001). Legumes hold a position of special significance within agricultural plants. They have the ability to capture (fix) atmospheric N_2 through the presence of rhizobia in root nodules makes their theoretically independent both of soil nitrogen status and extraneous fertilizer addition. Precipitation: Small amount of nitrogen are added to soil from precipitation. Nitrogen Fixed by Oceans (Voss, Bange, Dippner, middleburge, Montoya and Ward, 2013). Commercial Fertilizers: are also derived from the atmospheric nitrogen pool. The major step is to combine N_2 with H_2 (Hydrogen) to form (NH_3) ammonia Anhydrous ammonia is then used as a starting point in the manufacture of other nitrogen fertilizers. Anhydrous ammonia or other nitrogen products derived from NH_3 can then supplement other nitrogen sources for crop nutrition. (Industrial fertilizer production

(Fowler *et al.,* 2013). Animal Manures: Nitrogen can also become available for plant use from organic nitrogen sources which must be converted to inorganic forms before they are available as either ammonium (NH_4) or Nitrate (NO_3). Animals manures and other organic wastes can be important sources of nitrogen for plant growth. The amount of nitrogen supplied by manure will vary with the type of livestock, handling rate applied and method of application. Crop Resources: Crop residues from non-leguminous also contain nitrogen but in relatively small amounts compared to legumes. Nitrogen exists in crop residues in complex organic forms and the residue must decay (a process that can take several years) before nitrogen is made available for plant use. The application of crop residue can improve soil nitrogen dynamics through the improvement of water and Nitrogen use efficiency as well as the input of the substrate of soil organic matter (SOM). With a variety of management controlling influential facts, that is the quality, quantity timing and location of inputs of cop residue to the soil (Palm, Giller, Mafongoya, and Swift, 2001). Soil Organic Matters: Soil organic matter is also a major source of nitrogen used by crops. Researchers had shown that soil nitrogen is directly related to the organic matter content and with high total nitrogen content on surface soils due to high accumulation of organic matter. (Moges *et al* 2013). The major quantity of total nitrogen in the soil is its organic form, which makes soil organic matter a very important reserviour of available forms of nitrogen for plants, mainly in the forms of nitrate (NO_3-N) and ammonia (NH_3-N). Organic matter is composed primarily of rather stable material called humus that has collected over a long period of time. Soil contains approximately 2,000 pounds nitrogen in organic forms for each percent of organic matter.

2.4.2 Nitrogen Transformations:

Nitrogen undergoes many different transformations in the ecosystems, changing from one form to another as organisms use it for growth and in some cases, energy (Bernhard, 2010). The transformation of nitrogen into its many oxidation states is key to productivity in the biosphere and is highly dependent on the activities of a diverse assemblage of microorganisms, such as bacteria, archaea, and Fungi. Because of the importance of nitrogen in all ecosystems and the significant impact from human activities, nitrogen and its transformations have received a great deal of attention from ecologist.

The behavior of nitrogen in the soil exist in different forms. Nitrogen exist in the soil system in many forms and changes (transforms) very easily from one form to another. Nitrogen, present or added to the soil, is subject to several changes (transformation) that dictate the availability of nitrogen to plants and influence the potential movement of NO_3 to water supplies. Mineralization:- occurs when organic nitrogen present in soil organic matter, crop residues, and manure is converted to inorganic nitrogen. In this process bacteria digest organic material and release ammonium (NH_4^+) nitrogen. Formation of NH_4^+ increases as microbial activities increase. Bacterialgrowth is directly related to soil temperature and water content. Nitrification is the conversion of ammonium nitrogen (NH_4^+-N) to Nitrite ($NO_{2)}$, and Nitrate (NO_3).Nitrification occurs in soils at pH 5.5 and 10 but optimum around pH 7 (James, 2001). Most nitrification occurs aerobically and is carried out exclusively by prokaryotes. There are two distinct steps of nitrification that are carried out by distinct types of microorganisms. The first step is the oxidation of ammonia to nitrite by an organism known as nitrosomonas. The second step is the Oxidation of nitrite (NO_2) to nitrate (NO_3) by an organism known as nitrobacter. Denitification is the process by which bacteria convert NO_3^- (Nitrate) to nitrogen gas that is lost to the atmosphere. Denitrification is an anaerobic processes, occurring mostly in soils and sediments and anoxic zones in lakes and oceans. Dinitrogen gas (N_2) is the ultimate end product of denitrification, but other intermediate gaseous forms of nitrogen exist. Denitrifying bacteria uses NO_3^- nitrate instead of oxygen in the metabolic processes and where there is ample organic matter to provide energy for bacteria. For these reasons denitrification is generally limited to top soil. Denitrification is important in that it removes fixed nitrogen (nitrate) from the ecosystem and returns it to the atmosphere in a biological inert form. Immobilization:- occurs when nitrate and/or ammonium present in the soil is used by the growing microbes to build proteins. Immobilization and mineralization depend on a number of interrelated factors such as the physical and chemical properties of organic materials along with environmental variables and theses environmental variables are moisture and temperature (Brady and Weil, 1999). A temporal reduction in the amount of plant available nitrogen can occur from immobilization (tie up) of soil nitrogen. Bacteria that decompose high carbon-low nitrogen, such as corn stalks or small grain straw, need more to digest the material than is present in the residue.

Nitrogen Loss From The Soil: Nitrogen is lost from the soil system in several ways. Leaching:- is the loss of soluble nitrate as it moves with soil water. Nitrate can be leached from any soil if rainfall or irrigation moves water through the root zone. Denitrification is a major loss mechanism of nitrate when soils are saturated with water for 2-3 days. Nitrogen in the NH_4^+ ammonium form is not subject to this loss. Volatilization:- in this process, nitrogen is lost as the ammonia (NH_3) gas. Nitrogen can be lost in this way from manure and fertilizer products containing urea. Lossof nitrogen from volatilization is greater when soil pH is higher than 7.3, the air temperature is high, the soil surface is moist and there is a lot of residue on the soil. Crop Removal:- Substantial amounts of nitrogen are lost from soil system through crop removal. Crop removal accounts for a majority of the nitrogen that leaves the soil system. Soil Erosion and Runoff: - Nitrogen can be lost from agricultural lands through soil erosion and runoff. Where soils are highly erodible, conservation tillage can reduce soil erosion and runoff, resulting in less surface loss of nitrogen.

2.4.3Common Forms of Nitrogen:

plants are able to use only very specific inorganic forms of nitrogen. Organic nitrogen exists in many different forms. Organic nitrogen occurs in many forms.

There are certain biochemical processes especially those related to Nitrogen mineralization and immobilization, soil organic and inorganic nitrogen fractions could be transformed from one form into another. It is essential to know that the forms of nitrogen determine its rate of assimilation by plants and microbes (Aririguzo, Osujieke, Ahukaemere and Imadojemu, 2019).

Nitrate (NO_3):- Nitrates are the predominant form of inorganic nitrogen in agricultural soils and are therefore used by many plant species (Bhattacharyya, 2019). Nitrate Nitrogen is very mobile, with concentrations often low in soils due to excessive leaching especially in the humid tropics, Particular South-eastern Nigeria with high intense rainfall undernourished and fragile soils (Hirel *et al*; 2011). Nitrate form of nitrogen is a concern to water quality. This is because nitrate is very mobile and easily move with water. The concern of nitrates and water quality is generally directed at ground water. However nitrates can also enter surface waters such as ponds, streams and rivers. NO_3 is highly soluble (dissolves easily) in water and is stable. Over a wide range of environmental conditions. It is easily transported in streams and ground water. Nitrates can also come from animal manure and nitrogen fertilizer. Nitrate in the soil result from natural biological processes associated with the decomposition of plant residues and organic matter (Killpack and Buchholz, 1993). Excessive use of Nitrogen fertilizer in agriculture has been one of the major sources of nitrate pollution in groundwater and surface water. Some other non- point sources for nitrate pollution in ground water are originated from livestock feeding, animal and human contamination and municipal and industrial waste. Since ground water often serves as the primary domestic water supply, nitrate pollution can be extended from ground water to surface and drinking water in the process of potable water production, especially for small community water supplies, where poorly regulated and unsanitary waters are used (Fewtrell and Lorana, 2004). Nitrite (NO_2): is relatively short lived in water because it is quickly converted to nitrate by bacteria. Nitrite is toxic to plants.

Ammonium:- This is another inorganic form of nitrogen, and it is the least stable form of nitrogen in water. Ammonium exists in exchangeable and non exchangeable forms. Plant also use ammonium.(Uzoho *et al;* 2014) stated that ammonium nitrogen is usually fixed by clay, minerals, with availability often low in soils high in clay contents. Ammonia is easily transformed to nitrate in water that contain oxygen and can be transformed to nitrogen gas in waters that are low in oxygen. Ammonia is found in water in two forms. The ammonium in ion (NH_4^+) and dissolved unionized (no electrical charge) ammonia gas (NH_3). The dominant form depends on the pH and temperature of the water. The reaction between the two forms is shown by the equation $NH_3 + H_20 \quad NH_4^+ + OH^{-.}$

The form of ammonia changes easily when pH increases, H^+ concentration decreases, and OH^- concentration increases.

2.4.4 Factors Affecting Nitrogen Availability in Soil

Inherent factors such as rainfall and temperature and site conditions as moisture, soil alteration (oxygen levels) and salt contact (electrical conductivity/EC) affect rate of N mineralization from organic matter decomposition, nitrogen cycle and nitrogen losses through leaching, runoff, or denitrification. Soil type, crop rotation and management practices associated with tillage, stubble retention and fertilizer application can influence the diversity of microbal populations and along with the environment they affect biological processes involved in nitrogen fixation/mineralization and availability and losses. All of these processes and the associated microorganisms can be manipulated to optimize Nitrogen use efficient both by improving the supply of nitrogen from organic nitrogen and decreasing the losses through denitrification and leaching (Gupta, 2016). Nitrogen mineralized from soil organic matter and crop residues contributes to a large extent crop nitrogen requirements in the rainfed cropping regions across South Australia. Crop Rotation:- Such changes coupled with differences in the quantity and quality of organic residues (tops & roots) can significantly modify the nitrogen mineralization – Immobilization processes and availability of Nitrogen (McBerth, Gupta, Liewellun, and Davoren, 2015). Soil Type: One of the major factors influencingnitrogen are Percentage of clay content, soil moisture content and carbon availability. The percentage of clay content in the soil determines the abundance of free living nitrogen fixing bacteria in cropping soil. Also soil moisture content and carbon availability are major factors influencing free living nitrogen fixation in cropping systems. Therefore, remove of stubble one of the major sources of available carbon either by burning or grazing would have negative impact on the amount of nitrogen fixed by free-living nitrogen bacteria.

Soil pH: Soil pH affects both the host plant and the bacteria involved in the symbiotic relationship with regard to the forage plants, soil pH affects the uptake of nutrients from the soil. In general, a soil pH between 6.0 and 7.0 provides the best environment for optimum uptake by the forage plant. Therefore, maintaining the soil pH in this range to provide optimal plant growth and optimal Biological Nitrogen Fixation in many forage crops. Soil Fertility: In low fertility Australia, agricultural soils, crop residues are one of the major sources of carbon for soil brats and retention of stubble after harvest contributes to the conservation of nutrients taken up by the plant within the cropping system. A large portion of nitrogen used by crops is mineralized from the previous and pasture residues through the activity of microorganism. Climate: virtually any aspect of climate that affects crop growth rate will also affect Biological nitrogen fixation (BNT). Specifically, factors such as low air/soil temperature, lack of sunshine or drought will likely reduce BNT at least temporarily. Tillage Research from Victoria and South Australia has shown that tillage can disrupt the linkages between the activity of microbes processing organic Nitrogen and those related to fertilizer and mineral nitrogen transformations influencing the rate of release and accumulation of mineral nitrogen in soil (Phillips, Scheje, Fridman and Halloran, 2015). Tillage practices accelerate the decomposition and microbial turnover resulting in quick accumulation of mineral nitrogen especially in soils with lower microbial biomass lands. Plant Type: Research at Kaonde South Australia on a dune swale, landscape has shown that plant type e.g. wheat, cereal rife, canola or pasture can use large changes, in the functional diversity of microorganisms i.e. microbial communities, involved in various biological functions including nitrogen cycling processes. Thus in a crop rotation such changes coupled with differences in the quantity and quality of organic residues (top and roots) can significantly modify the nitrogen mineralization – immobilization processes and availability of nitrogen (Mc Beath, Gupta, Liewellun and Davoren, 2015). Management strategies such as stubble retention can influence the diversity of microbial populations and along with the environment, they affect biological processes involved in nitrogen fixation, mineralization and availability and losses. Nitrogen is mineralized from soil organic matter and crop residues and they contribute to a large part of crop nitrogen requirements in the rainfed cropping regions. Stubble retention can provide benefits through changes in soils physical, chemical and biological properties (Gupta, 2016). Nitrogen released during decomposition and soil organic matter turnover is rapidly assimilated by microbial biomass which is subsequently released through microbial turnover and microbe fauna interactions.Mostof the nitrogen (N) used by Australian crops is mineralized from the residues of previous crops and pastures (Angus, Bolger, Kirkegaard, and Peoples, 2016). Retained stubble conserve soil water, leading to periods of increased mineralization. Fertilizer Application: The conversion of ammonia and urea nitrogen found in commonly used nitrogen fertilizers into nitrate nitrogen is a biological process mediated by specific group of microorganisms, example. Nitrifiers, which are mostly abundant in the surface soils. Research has shown that barding fertilizers can influence the activity of these microbes and the accumulation of nitrate nitrogen (Angus, Gupta, Pitson, and Good 2014). This fertilizer nitrogen use efficiency could be manipulated by targeting fertilizer placement on the use of nitrification inhibitors.

CHAPTER THREE

3.0 Materials and Method

3.1 The Study Area

Reconnaissance visit was carried out on the study areas to identify the river floodplains. The sites were randomly selected. The study was carried out in three locations in Imo State, South East Nigeria. These include Ngbele in Oguta local Government Area located on latitude 5.680^0 N and longitude 6.8478^{0}E, Obiakpo in Ohaji Egbema Local Government Area located on latitudes 5.6011^{0}N and longitude 6.7447^{0}E and Onumiri Emeabiam in Owerri West Local Government Area located between latitudes 5.4242^{0}N and longitudes 6.4834^{0}E all in Imo State, South Eastern Nigeria (Fig 1). The study area lies within the rain forest vegetation zone with different plant species. The hydrology of the area is wetland governed by Oguta lake (Oguta), Otamiri river (Emebiam) and Nkesi river (Ohaji Egbema). The areas are characterized by a flat relief and hydrophism which is caused by both high water table and seasonal flooding**.** The climate is humid tropical with rainfall of about 2500mm, mean temperature of 27^0 and 28^{0}C and relative humidity of 75 to 80% (NIMET, 2018). The area is characterized by two seasons, the dry and rainy seasons. The vegetation of the study areas consist of some common plant species especially yam, maize, coconut, oil palm, rubber, goat weed andelephant grass. The socio-economic activities of the areas include farming, fishing, hunting, crude oil mining, sand mining, and trading. Soil fertility regeneration is by bush fallowing. Tropical rain forest is the dominant vegetation of the area, though remarkable ecological diversity caused by anthropogenic activities especially farming and deforestation resulting in depleted vegetation as a result of demographic pressure (Onwudike,2015). Economic trees like Bamboo, rubber plants, oil plam, Gmelina are in abundance.

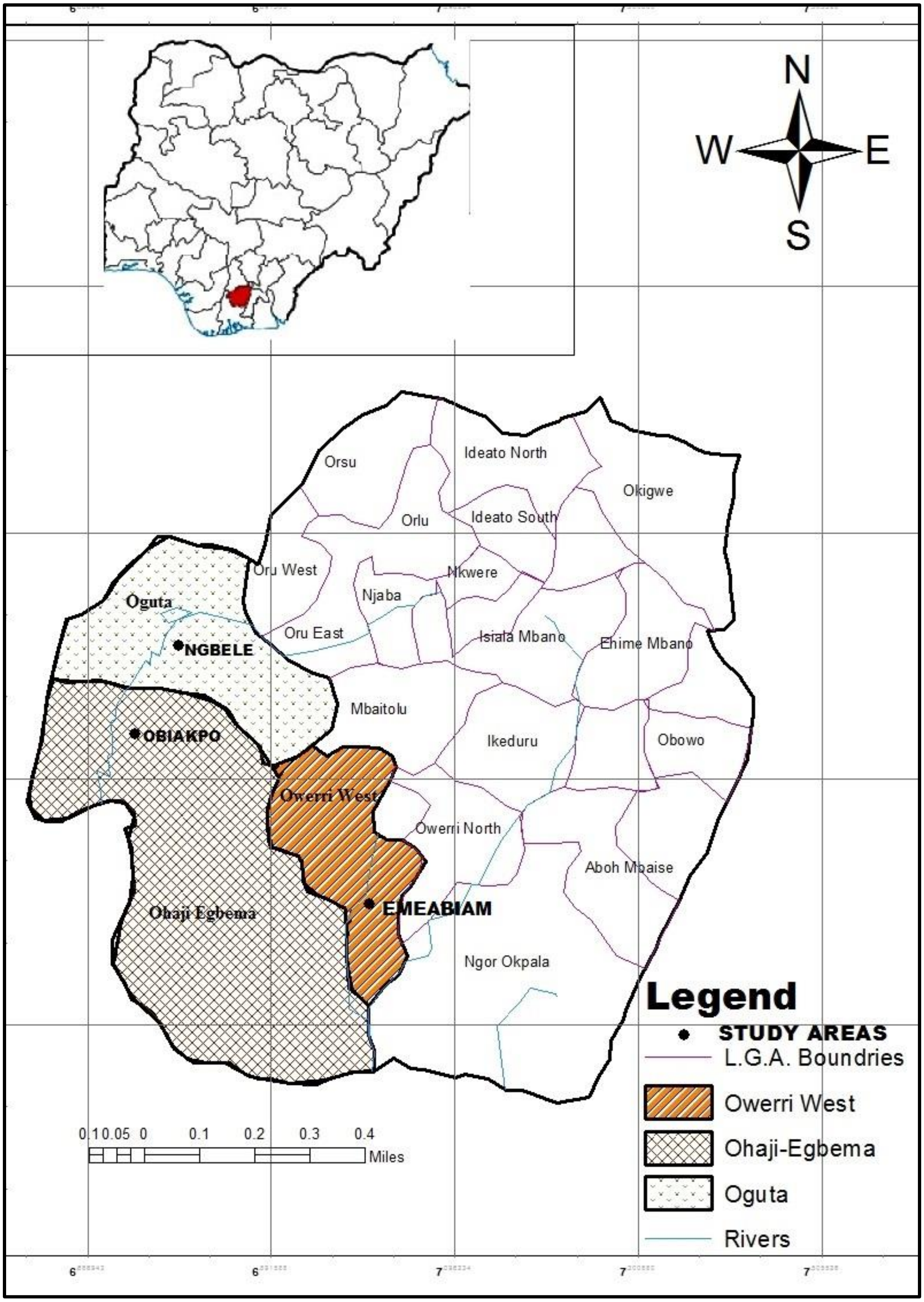

Figure 1: Location Map of Study Area

3.2 Field Study.

Reconnaissance visit was carried out on the study areas and sample sites. Thesites were randomly selected. Three profile pits were dug in each location. A total of nine (9) profile pits were used. Description and sampling were done according to FAO (2006) guidelines. Delineation of horizon boundaries was done before sample collection for various laboratory analysis. Undisturbed core samples were collected for bulk density determination. Laboratory analysis of the samples was done in Soil Science and Technology laboratory, Federal University of Technology Owerri. Soil colour was done using Munsel soil colour chart. Macro-morphological properties were determined insitu using visual observations, hand feeling and measurement. These included depth to water table, colour matrix (moist) using munsel colour chart, fauna activities, presence of mottle, vegetation, drainage conditions, profile depth, land form and surface structure.

3.3 Sample Collection and Preparation

The soil samples collected from the three locations namely Emeabiam, Ohaji Egbema and Oguta were air dried, sieved with 2mm wire mesh sieve. The samples were subjected to routine soil laboratory analysis to determine the physical and chemical characteristics of the soil.

3.4 Laboratory Analysis

3.4.1 Particle Size Distribution: This was determined using modifiedBouyoucos hydrometric method as described by (Gee and Or, 2002). Textural triangle was used to establish textural classes.

3.4.2 Bulk Density:- This was determined by the core sampling method

(Grossman and Reinsch, 2002). In this, the undisturbed soil samples collected were weighed before and after drying to constant weight in anoven and, the bulk density calculated using the following equations.

$$Bd(gcm^{-3}) = \frac{\text{Weight of oven dry soil}}{\text{Volume of core}}$$ ………….………Equation 3.

3.4.3 Total Porosity:- Total Porosity (TP) was obtained from bulk density(BD) assumed particle density (PD) 2.65g cm^{-3}as follows:

$$TP \quad 1 - \frac{BD}{PD} \text{ x } 100$$ ……………..Equation 3.2

3.4.4 Soil pH: - This was determined in water and KCl using the Beckman

Zeromatic pH meter (Thomas, 1996).

3.4.5Percentage Organic Carbon: The Soil Organic Carbon was determined using the Walkley and Black Wet Oxidation method (Nelson and Sommers, 1982).

3.4.6 Soil Organic Matter: - This was determined by multiplying soil organic carbon with Van Bemmellin factor of 1.724.

3.4.7 Available Phosphorus: it was determined calorimetrically using Bray 11

(Olson and Sommers, 1982)

3.4.8 Exchangeable Bases: Cations (Ca,Mg, k, Na) were extracted using 1N, NH_4OAcbuffered at pH_7, Potassium (K) and Sodium (Na) were determined

Usingthe flame photometer (Udo *et al*.,2009) while Calcium (Ca) and Magnesium

(Mg)were determinedusing the Atomic Absorption Spectrophotometer (AAS).

3.4.9 Exchangeable Acidity: - It was determined by titration IN KCL extracting solution with 0.5NNaOH using phenolphthalein indicator as described by (Udo *et a.,l*2009).

3.4.10 Effective Cation Exchange capacity: was gotten from the summation of all

exchangeable bases (Ca, Mg, K, Na) and acidity (TEB + TEA).

3.4.11 Exchangeable basic cation(Ca^+, Mg^+, K^+, Na^+): determined by using IN NH_4OAC buffered at pH of 7, while K and Naare by flame photometer (Udo *et al*., 2009). While Ca and Mg by Atomic Absorption Spectrophotometer (ASS)

3.4.12 Percentage Base Saturation: - was calculated by dividing total exchangeable bases by effective cation exchange capacity value multiplied by hundred.

3.4.13 Aluminium Saturation:- (AL^{-3}) = mathematically as the ratio of exchangeable Al to effective cation exchange capacity multiplied by hundred.

$$\text{Alsat} = \frac{A1}{ECEC} \text{ x } 100 \text{………….Equation 3.4}$$

3.4.14 Total Nitrogen:- This was determined by the macro-Kjedahl digestion and distillation method of Bremmer as modified by (Udo *et a.,l* 2009).

3.4.15 Ammonium NH^{4+}: Was determined in a spectrophotometer as described by

(Udo *et al*., 2009).

3.4.16 Nitrate (NO_3);- Nitrate was determined with the calorimetric method using a spectrophotometer as described by (Udo *et al.*, 2009).

3.4.17 Nitrite (NO_2): was determined with the calorimetric method using spectrophotometer (Udo *et al*., 2009).

Fertility Status: The fertility status of the soil was determined by comparing the soil fertility parameters especially pH, texture, P,N, Ca etc with the critical limit of Esu (1991) and

Landon,(1991). Also the elemental ratios (Ca: Mg, k: Mg etc) were used to determine the fertility status of the soil.

Statistical Analysis:- Data generated from soil physico-chemical properties and Nitrogen forms were subjected to Analysis of Variance (ANOVA). And the Means separated using Least Significant difference (LSD) at 5% probability Level. Relationship between nitrogen forms and soil properties was determined using correlation analysis.

CHAPTER FOUR

4.0 Results and Discussion

4.1 Soil Morphological Properties

The morphological properties of the soils of Emeabiam, Ohaji Egbema and Oguta as presented on Tables 4.1a, 4.1b and 4.1c respectively were used for the distinction and classification of the various soils. The colour for Emeabiam soil pedon 1 ranged from dark grayish brown (2.5 YR 4/7) at the top to brownish yellow (10 YR 6/6) at the sub soil. This brownish colour indicates good aeration and organic matter content. The colour of Pedon 2 ranged from dark gray (5YR 4/1) at the surface to olive gray (5YR 4/2) at the sub surface,Withdarker moist matrix of the pedon for the forest soils ascribed to constant litter decomposition and organic matter decomposition, while the greyish colour indicates constant water saturation. Pedon 3 ranged from light grey (5Y 7/1) at the surface to grayish brown (2.5Y5/4) at the sub surface. This grey colouration for some Emeabiam soils couldbe attributed to poor aeration due to water logging. Generally, the greyishness of most of the pedons signified wet and dry cycles due to flooding and restricted drainage (Akpan Idioku & Esu, 2001). In summary, Emeabiam Pedon1 was well drained while pedon 2 and 3 were water logged. Emeabiam soil was granular in structure at the surface and Sub angular Blocky at the sub surface of pedon 1, while pedon 2 and 3 of Emeabiam soils were sub angular blocky in structure at the surface and angular blocky at the subsurface horizons in all the pedons. Also Ohaji Egbema had granular structures at the surface and sub angular blocky at the sub surface. Oguta soils had granular structure at the surface in all the pedons and subangular blocky at the subsurface horizon in pedon 1 and 2 while pedon 3 had angular blocky. Soil structure reflects the susceptibility of soils to agents of erosion and degradation as soils with large particles are easily eroded when compared to soils with finer particles (Evans, 1980). Emebiam soils were sticky and poorly drained due to the wet condition of the place especially pedons 2 and 3 while pedon 1 was friable at the surface and firm at the subsurface horizon. Ohaji was friable at surface and firm at the subsurface horizon. Oguta had friable consistency in all the pedons. The texture of Emeabiam soils wassandy in pedons 2 and 3 while pedon 1 was loamy sand. The matrix colour of Pedon 1 in Ohaji Egbema ranged from light olive brown (2.5Y5/4) at the surface to yellow (2.5Y8/8) at the subsurface. Pedon 2 ranged from very dark gray (5Y3/1) to pale brown (5Y7/4) and pedon 3 ranged from black (2.5Y2/0) at the surface to light olive brown (2.5Y 5/6) at the subsurface. This brown colour is an indication of good aeration and organic matter content. Ohaji Egbema and Oguta soils weregranular in structure at the surface and sub angular blocky at the subsurface horizons in all. Oguta moist matrix colour ranged yellowish brown (10YR5/6) at the surface to (10YR 8/6) yellow at the subsurface of pedon 1. Pedon 2 ranged dark yellowish brown (10YR 4/6) to yellow (10YR 7/8). While pedon 3 ranged yellowish brown (10YR5/6) to yellow 10YR 7/8. The yellowish colour of Ohaji Egbema and Oguta soils can be as a result of the presence of iron. (feromagnessium oxide). Emeabiam and Ohaji Egbema had animal activities at the surface and sub surface. Emeabiam had many roots while Ohaji Egbema and Oguta had many roots at the surface and few at the subsurface. Boundary varied in all the locations. Emeabiam soils were wet except pedon 1 that was well drained. Akamigbo (2006) reported that floodplain soils are generally poorly drained apparently due to the flat and lowlying topography in which these soils are found, making them liable to flooding. The pedons of Emebiam were poorly drained. This finding agrees with the report of Idoga and Ogbu (2006) who reported that the striking feature of floodplain soils is poor drainage as manifested by their colour. Ohaji Egbema and Oguta soils were moist and well drained. Emeabiam had few mottles in pedon 1 and none in pedon 2 and 3 while Ohaji Egbema had many mottles at the subsurface horizons in all the pedons. Oguta had few mottles at the subsurface in pedon 1 and 2. The difference in colour and presence of mottles is due to high degree of hydration and redox reaction as a result of fluctuating underground water table within the zone (Adamu *et al.,* 2015).

TABLE 4.1a Morphological Properties of Soils of Emebiam

Location (EWS)	Horizons	Depth	Colour	Structure	Consistency	Animal Activity	Roots	B/D	Drainage	Mottles
Pedon 1	Ap	0-12	2.5 YR 4/7 dark grayish brown	Granular	Very friable	Many	Many	dc	Wd	None
	AB	12-31	2.5 YR 6/7 dark light brownish gray	Granular	Friable	Many	Many	dc	Wd	None
	BA	31-66	2.5 YR 5/4 light olive brown	Granular	Friable	Few	Many	dc	Wd	None
	Bt1	66-135	10 YR 4/6 dark yellowish brown	SAB	Firm	Few	Many	ds	Wd	None
	Bt2	135-200	10 YR 6/6 brownish yellow	SAB	Firm	None	Many	Sc	Wd	None
Pedon2										
	AP	0-8	5 YR 4/1 dark gray	SAB	Firm	Many	Many	Ws	Pd	None
	A	8-24	5 YR 3/1 very dark gray	AB	Sticky	Many	Many	Ws	Pd	None
	AB	24-42	5 YR 5/2 Olive gray	AB	Sticky	Many	Many	Ws	Pd	None
Pedon3	AP	0-6	5 Y 7/1 light gray	SAB	Firm	Many	Many	Ws	Pd	None
	A	6-18	5 Y 5/2 Olive gray	AB	Sticky	Many	Many	Ws	Pd	None
	AB	18-46	2.5 Y 4/4 Olive brown	AB	Sticky	Few	Many	Ws	Pd	None
	BA	46-98	2.5 Y 5/4 grayish brown	AB	Sticky	Few	Many	Ws	Pd	None

EWS; Emeabiam Water Side, Structure: SAB= Sub angular blocky, Boundary: ds= Diffuse, SC= Smooth and Clear, dc =diffuse and clear Texture : Ls= Loamy Sand, S= Sand, Drainage: Wd= well drained, Pd = poorly Drained, Ws = Wavy and Smoo

TABLE 4.1b Morphological Properties of Soils of Ohaji Egbema

Location (Egbe)	Horizons	Depth	Colour	Structure	Consistency	Animal Activity	Roots	B/D	Drainage	Mottles
PEDON 1	Ap	0-13	2.5Y 5/4 light olive brown	Granular	friable	Many	Many	ds	Wd	None
	A	13-34	2.5Y 6/4 light yellowish brown	Granular	Friable	Many	Many	Sc	Wd	None
	AB	34-60	2.5Y 7/4 pale yellow	SAB	Firm	Many	Many	Sc	Wd	Few
	Bt1	60-85	2.5Y 7/8 yellow	SAB	Firm	Few	Many	ds	Wd	Few
	Bt2	85-200	2.5Y 8/8 yellow brown	SAB	Firm	Few	Few	ds	Wd	Many
PEDON 2										
	Ap	0-9	5Y 3/1 very dark gray	Granular	Friable	Many	Many	Sc	Wd	None
	A	9-28	5Y 5/3 olive	Granular	Friable	Many	Many	Sc	Wd	None
	AB	28-50	5Y 6/6 olive yellow	SAB	Firm	Many	Many	Sc	Wd	Few
	Bt1	50-90	5Y 7/6 yellow	SAB	Firm	Few	Few	ds	Wd	Many
	Bt2	90-200	5Y7/4pale brown	SAB	Firm	Few	Few	ds	Wd	Very many
PEDON 3										
	Ap	0-9	2.5Y 2/0 black	Granular	Friable	Many	Many	ds	Wd	None
	A	9-26	2.5Y 4/4 olive brown	Granular	Friable	Many	Many	Sc	Wd	None
	BA	26-46	2.5Y 6/6 olive yellow	SAB	Firm	Few	Many	ds	Wd	Few
	Bt1	46-67	2.5Y 5/6 light olive brown	SAB	Firm	Few	Few	ds	Wd	Few
	Bt2	67-150	2.5Y 5/6 light olive brown	SAB	Firm	Few	Few	ds	Wd	Many

Structure: AB= Angular blocky, SAB= sub angular blocky, **Boundary**: ds= Diffuse, sc= Smooth and Clear, **Texture** : Ls= Loamy Sand, Sl= Sandy loamy, S= Sand, SCL = Sandy Clay Loam, **Drainage:** Wd= well drained, Egbe = Egbema.

TABLE 4.1C Morphological Properties of Soils of Oguta

Location (OGU)	Horizons	Depth	Colour	Structure	Consistency	Animal Activity	Roots	B/D	Drainage	Mottles
Pedon 1	A	0-10	10YR5/6 Yellowish brown	Granular	Friable	Few	Many	Sc	Wd	None
	BA	10-47	10YR 6/8brownish yellow	Granular	Friable	Few	Many	Sc	Wd	None
	Bt1	47-82	10YR 7/6 Yellow	Granular	Friable	Few	Many	Sc	Wd	None
	Bt2	82-136	10YR 7/8 Yellow	SAB	Friable	None	Few	Sc	Wd	Few
	Bt3	136-200	10YR 8/6 Yellow	SAB	Friable	None	Few	Sc	Wd	Many
Pedon 2	A	0-12	10YR 4/6 dark Yellowish brown	Granular	Friable	Few	Many	Sc	Wd	None
	BA	12-53	10YR 5/8 Yellowish brown	Granular	Friable	Few	Many	Sc	Wd	None
	Bt1	53-75	10YR 6/8 brownish Yellow	SAB	Friable	None	Few	ds	Wd	None
	Bt2	75-112	10YR 7/6 Yellow	SAB	Friable	None	Few	ds	Wd	Few
	Bt3	112-200	10YR 7/8 Yellow	SAB	Friable	None	None	SC	Wd	Few
Pedon 3	A	0-10	10YR 5/6 Yellowish brown	Granular	Friable	Few	Many	Sc	Wd	None
	BA	10-36	10YR 6/6 brownish Yellow	Granular	Friable	Few	Many	Sc	Wd	None
	Bt1	36-78	10YR 6/8 brownish Yellow	SAB	Friable	Few	Many	Sc	Wd	None
	Bt2	78-126	10YR 7/4 Very Pale Brown	SAB	Friable	Few	Few	ds	Wd	None
	Bt3	126-200	10YR 7/8 Yellow	SAB	Friable	Few	Few	ds	Wd	None

STRUCTURE: SAB= Sub angular blocky, AB= Angular blocky, B/D = Boundary Distance, Wd= Well drained,SC= Smooth and Clear, TEXTURE: S= Sand , ds = diffuse

4.2 Physical Properties of the Soils of Studied Locations.

The physical properties of soils derived from floodplains on diverse parent materials are presented in Tables 4.2a, 4.2b, 4.2c. The average sand content of soils of Emeabiam ranged from $845.2kg^{-1}$ to $900.7kg^{-1}$. The textural class was sandy in all the pedons.The predominance of sand in particle size distribution is typical of tropical soils especially of savannah ecosystem where Maniyaunda and Raji (2018) had already reported a similar dominance of sand. Soils with high sand content are prone to soil erosion and leaching. Most floodplain soils are sandy (Akamigbo, 2001). The clay content of the soils increased with depth generally showing translocation processes. The silt mean value ranged from $7.8kg^{-1}$ to $10.2kg^{-1}$. The silt mean value was very low in all the pedons. The mean value for clay ranged from $61.0kg^{-1}$ to $78.0kg^{-1}$. Silt Clay Ratio (SCR) of Emeabiam soils were 0.15, 0.16 and 0.17 in pedon I,2 and 3 respectively. Silt Clay ratio mean values for Ohaji Egbema were 1.39, 1.29, and 1.90 in pedon 1,2 and 3. While The silt clay ratio (SCR) mean values for Oguta soil were 0.39, 0.34 and 0.44 for pedons 1,2 and 3 respectively. VanWambeke,(1962); Yakubu and Ojanuga (2009), had reported that SCR below 0.15 was indicative of an old soils while SCR above 0.15 was indicative of a young soil with weatherable reserves. Also soils of thestudied locations could be seen as young soils. The mean values for bulk density were $1.50gcm^{-3}$, 1.68 gcm^{-3}, and1.48 gcm^{-3} in pedon 1,2 and 3 respectively. Esu (2010) reported that bulk density value less than 1.60 gcm^{-3} is an indication that air and water movement in the soil are at optimum. The bulk density values were within the range for rooting crops. The total porosity mean values ranged from 36.6% to 48.0%.

The textural classes of soils of Ohaji Egbema included sand, loamy sand, sandy loamy and sandy clay loam. The surface soils had different textures from the sub-surface horizons. This result is in agreement with those reported by Akamigbo (2005), that the textures of floodplain soils are variable and that those variations may be due to differences in parent materials and topography. The AP horizons of pedon 1,2 and 3 were all sand. The sub surface horizon was either loamy sand (LS) sandy loam (SL), sandy clay loam (SCL). Maniyaunda and Raji (2018) had already reported a similar dominance of sand. Soils with high sand content are prone to soil erosion and leaching. The mean values of sand were 850.9kg^{-1}, 760.3kg^{-1} and 657.7gkg^{-1}in pedon 1,2 and 3 respectively. The means of silt were 80.8 kg^{-1}, 118.8 kg^{-1} and 205.1 kg^{-1} for pedons 1,2 and 3. The mean values for clay were 68.3kg^{-1}, 120.9kg^{-1} and 137.2kg^{-1}respectively in pedon 1,2 and 3 respectively.TheMean values for bulk density were 1.25gcm^{-3}, 1.18gcm^{-3} and 1.17gcm^{-3} in pedon 1,2 and 3 respectively. The bulk density was low. This also agrees with the works of Ahukamere *et al* (2014) where they reported values of bulk density ranging from 1.26gcm^{-3} to 1.48gcm^{-3}.Total porosity ranged from 52.9% to 55.74%. High porosity of Ohaji Egbema soils could be as a result of good aggregation. The soils of Oguta were all sandy. According to Akamigbo, (2001) most floodplain soils are sandy. Mean values for were 945.6kg^{-1}, 950.6 kg^{-1},and 950.3kg^{-1} in pedon 1,2 and 3. The high content of sand in the soils was therefore a reflection of the quartziferous nature of parent material or rock and also the high intensity of chemical weathering going on in the profile (Nkwopara, 2006).GenerallyOguta soils developed on the coastal plain sand had more sand texture compared to Emeabiam and Ohaji Egbema that are developed on river floodplainindicating the influence of parent material on soil texture. According to Ahukaemere (2015), soil texture is an inherent property of the soil and can only be influenced by parent material from which soils are developed. Siltmean values were 14.8kg^{-1}, 12.3kg^{-1} and 14.7kg^{-1} and this was low. Clay mean values were 39.5kg^{-1}, 39.1kg^{-1}, and 34.8kg^{-1}. This was also low. Bulk density mean value ranged 1.53gcm^{-3}, 1.34gcm^{-3}, and 1.37gcm^{-3}. The bulk density. of soils are considered safe for root penetration. Root penetration might be hindered in soil having bulk density above 1.75cmg^{-3}(Esu 2005). This is within the range of good rooting crops. Mean values for total porosity ranged from 42.2% to 49.7%.

TABLE 4. 2aPhysical Properties of Soils of Emeabiam.

Horizons	Depth cm	Sand g/kg	Silt g/kg	Clay g/kg	Silt /Clay	Bulk/D	T/P %	T/ class
			EME PEDON 1					
Ap	0-12	903.2	10.2	48.0	0.21	1.49	3.7	S
AB	12-31	863.2	13.6	58.0	0.23	1.29	51.2	S
BA	31-66	843.2	10.1	78.0	0.13	1.36	49.1	S
Bt1	66-135	813.2	9.0	98.0	0.09	1.59	40.4	S
Bt2	135-200	803.2	8.2	108.0	0.08	1.76	33.9	LS
Mean		**845.2**	**10.2**	**78.0**	**0.15**	**1.50**	**43.6**	
CV		**4.762**	**20.18**	**32.69**	**46.42**	**12.42**	**15.9**	
			EME PEDON 2					
Ap	0-8	893.2	13.2	46	0.29	1.52	42.6	S
A	8-24	863.2	8.0	76	0.11	1.78	32.8	S
AB	24-32	853.2	7.0	86	0.08	1.74	34.3	S
Mean		**869.9**	**9.4**	**69.3**	**0.16**	**1.68**	**36.6**	
CV		**2.393**	**35.41**	**30.02**	**70.99**	**8.311**	**14.4**	
			EME PEDON 3					
Ap	0-6	923.2	11.3	36	0.31	1.42	**46.4**	S
A	6-18	913.2	11.0	46	0.24	1.39	47.9	S
AB	18-46	883.2	5.4	76	0.07	1.00	62.3	S
BA	46-98	883.2	3.6	86	0.04	1.71	35.5	S
Mean		**900.7**	**7.8**	**61.0**	**0.17**	**1.48**	**48.0**	
CV		**2.289**	**49.98**	**39.02**	**79.25**	**10.3**	**22.9**	

EWS: Emeabiam , CV Coefficient of variation, T/P = Total Porosity, T/C = Textural Class.

TABLE 4. 2b Physical Properties of Soils of Ohaji Egbema.

Horizons	Depth cm	Sand g/kg	Silt in g/kg	Clay g/kg	Silt /Clay	Bulk/D	T/P %	T/Class
			EGBE PEDON 1					
Ap	0-13	928.1	32.8	39.2	0.84	1.24	53.2	S
A	13-34	875.2	82.8	42.0	1.97	1.20	54.7	S
AB	34-60	868.0	92.8	39.2	2.37	1.23	53.6	S
Bt1	60-85	828.2	82.8	89.2	0.93	1.27	52.1	S
Bt2	85-200	755.2	112.8	132.0	0.85	1.30	50.9	LS
Mean		**850.9**	**80.8**	**68.3**	**13.9**	**12.5**	**52.9**	
CV		**7.55**	**36.50**	**60.70**	**52.08**	**3.14**	**2.7**	
			EGBE PEDON 2					
Ap	0-9	795.2	152.8	52.0	2.94	1.19	55.1	S
A	9-28	815.2	92.8	92.0	1.01	1.12	57.7	S
BA	28-50	768.0	122.8	109.2	1.12	1.17	54.7	LS
Bt1	50-90	738.0	122.8	139.2	0.88	1.20	53.2	LS
Bt2	90-200	685.2	102.8	212.0	0.48	1.24	53.2	SL
Mean		**760.3**	**118.8**	**120.9**	**1.29**	**1.18**	**54.78**	
CV		**6.72**	**19.38**	**49.56**	**74.32**	**22.25**	**3.4**	
			EGBE PEDON 3					
Ap	6-9	835.2	132.8	32.0	4.15	1.16	56.2	S
A	9-26	768.0	122.8	109.2	1.12	1.13	57.4	Ls
BA	26-46	695.2	122.8	182.0	0.67	1.14	56.9	Ls
Bt1	46-67	354.8	413.2	232.0	1.78	1.21	54.3	SCL
Bt2	67-150	635.2	233.8	131.0	1.78	1.22	53.9	LS
Mean		**657.7**	**205.1**	**137.2**	**1.90**	**1.17**	**55.74**	
CV		**28.17**	**61.15**	**55.11**	**70.67**	**3.49**	**2.8**	

Egbe: Egbema, CV Coefficient of variation, T/P = Total Porosity, T/C = Textural Class

TABLE 4. 2c **Physical Properties of Soils of Oguta.**

Horizons	Depth cm	Sand g/kg	Silt in g/kg	Clay g/kg	Silt /Clay	Bulk/D	T/P %	T/C
			OGU PEDON 1					
A	0-10	940.8	22.8	36.4	0.62	1.501	**43.4**	**S**
BA	Oct-47	955.2	12.8	32.0	0.4	1.454	45.3	S
Bt1	47-82	940.8	22.8	36.4	0.63	1.408	46.8	S
Bt2	82-136	950.6	2.8	46.4	0.06	1.576	40.8	S
Bt3	136-200	940.8	12.8	46.4	0.28	1.726	34.7	S
Mean		**945.6**	**14.8**	**39.5**	**3.9**	**1.53**	**42.2**	
CV		**0.722**	**56.53**	**16.53**	**60.42**	**8.12**	**11.3**	
			OGU PEDON 2					
A	0-12	965.2	12.8	32.0	0.4	1.302	50.9	**S**
BA	12-53	950.8	10.8	38.4	0.28	1.262	52.5	S
Bt1	53-75	940.8	12.8	46.4	0.288	1.29	51.2	S
Bt2	75-112	950.8	2.4	46.8	0.05	1.273	52.1	S
Bt3	112-200	945.2	22.8	32.0	0.71	1.582	40.4	S
Mean		**950.6**	**12.32**	**39.12**	**3.4**	**1.34**	**49.7**	
CV		**0.968**	**58.95**	**18.69**	**69.5**	**14.7**	**10.3**	
			OGU PEDON 3					
A	0-10	935.2	32.8	32.0	1.03	1.274	52.1	**S**
BA	10-36	940.8	12.8	46.4	0.28	1.467	44.9	S
Bt1	36-78	955.2	12.8	32.0	0.41	1.381	47.9	S
Bt2	78-126	955.2	12.8	32.0	0.4	1.365	48.7	S
Bt3	126-200	965.4	2.6	32.0	0.08	1.34 0	49.4	S
Mean		**950.3**	**14.7**	**34.8**	**4.4**	**1.37**	**48.6**	
CV		**1.283**	**74.59**	**18.46**	**80.82**	**5.765**	**5.4**	

Ogu = Oguta, T/C = Textural Class , TP = Total Porosity, CV = Coefficient of Variation

4.3 Chemical Properties of Soil.

Results of the chemical properties of the soil are shown in Table 4.3a,b,and c

The mean values of pH for Emeabiam soil ranged from 5.55 to 6.32 which is moderately acidic. Ohaji Egbema mean ranged from 5.74 to 6.22 which is moderately` acidic, while Oguta mean ranged from 6.25 to 6.32 which is also slightly acidic. This pH value is an indication that significant amount of exchangeable AI^{3+} and $H^{+}$is present to affect plant growth. Udo *et al.*, (2009) had established pH range of 5.5-7.0 as optimal for overall satisfactory availability of plant nutrients, the values obtained from this study in all the locations are within the range. Nevertheless, the soil could be utilized for crop cultivation with judicious application of lime.

Organic Carbon (OC) of Emebiam had mean values that ranged from 0.46% to 0.90% in Pedon 1, 2and 3 which is low. Ohaji Egbema mean value ranged from 0.52% to 0.95% in Pedon 1, 2 and 3 which is also low, while Oguta had 0.22%, to 0.90% in Pedon 1, 2 and 3 this is also low (Esu 1991). Organic Carbon content (OC) decreased with increasing soil depth, probably due to decreased faunal activities in the underlying horizons (Browaldh, 1995; Lawal, Tsado, Eze, Idefoh, Zaki, and Kolawole, 2014). The low levels of organic carbon detected on the floodplain soils of the study area could be attributed to continuous cultivation of farmland and low organic matter.

Organic matter (OM) content of the soils mean ranged from 0.79% to 1.73% in Emeabiam. Ohaji Egbema ranged from 0.93% to 1.55% , while Oguta mean ranged from 0.36% to 0.66%. The organic matter was generally low in all the pedons and below the rating of FAO (2004).Low organic matter could be as a result of texture, climate and vegetation. The low content of organic matter in the soils could be attributed to major reason namely human activities through bush burning and continuous cultivation. These activities disrupt the process of organic matter recycling. High rate of organic oxidation due to high temperature and high microbial activities can also account for the low organic matter content of these soils (Eshett, 1990). The results also showed that organic matter decreased down the soil depth in all the studied Pedons. The high values of organic matter at the A horizon were in conformity with the works of Eshett (1989) and Igwe, Akamigbo, and Mbagwu, (1995), in South Eastern Nigeria.

Mean totalnitrogen ranged from 0.08%to 0.13%, 0.09% to 0.10%, 0.04% to 0.08%. for Emeabiam, Ohaji Egbema and Oguta respectively.Total nitrogen was low in all the pedonsStudied. Total nitrogen also decreased with depth in Emeabiam and Ohaji Egbema while Oguta total nitrogen changed irregularly with depth. The low values observed could be attributed to the continuous cultivation which is aggravated by the unwelcomed habit of complete removal of crop residues after harvest by farmers and this deprived the soils of its organic matter turnover and losses through leaching. Noma (2012) gave a similar report on the low TN values of some floodplain soils. Total nitrogen followed a similar trend as soil organic matter since, organic matter contributes the bulk of total nitrogen for tropical soils (Noma, Ojanuga, Ibrahim, and Liya, 2005). Total nitrogen values of Emeabiam and Oguta were below 0.15% the critical value for tropical soils.

Ahukaemere (2015) states that low nitrogen concentration is a common phenomenon in the soils of South Eastern Nigeria. The variation can be linked with the amount of organic matter deposit, rate of mineralization and leaching. Variation in total nitrogen distribution with depth has been widely reported (Onweremadu *et al* 2011, Zhijing *et al* 2013). The A horizon contains more total nitrogen over the horizons which shows that mineralization is higher in the surface horizons of the studied pedons. Total nitrogen contents play a crucial role in maintaining soil quality, improve crop production (Bauer and Black, 1994) and environmental sustainability.

Available Phosphorus was generally low in all the studied locations. Mean values ranged from

3.46mgkg^{-1} to 10.74 mgkg^{-1}, 4,62mgkg^{-1} to 6.80mgkg^{-1} and4.20mgkg^{-1} to 4.62mgkg^{-1} for Emeabiam, Ohaji Egbema and Oguta respectively. Available Phosphorus was below critical value (15mgkg^{-1}) according to the ratings of Esu (1991). In an acidic soil, P can form complexes with Fe, Al and Mn, while in an alkaline soils, complexes are formed with Ca, hence P availability is greatly restricted by the soil pH and climatic condition – higher P in rain forest zones than in savanna grassland (Osodeke, 2017).MeanCa^{++} values for surface and subsurface horizons ranged from 2.03cmol/kg to 3.52cmol/kg, 1.92cmol/kg to 2.14cmol/kg and 1.06cmol/kg to1.34 cmol/kgfor Emeabiam, Ohaji Egbema and Oguta respectively. Emeabiam, Ohaji Egbema and Oguta were low in calcium. Exchangeable Magnesium (Mg^{2+}) was generally low in all the location studied. Emebiam mean values ranged from 0.91cmol/kg to 1.62cmol/kg. Ohaji Egbema mean values ranged from 0.92cmol/kg to 1.33cmol/kg, whileOguta mean values ranged from 0.5cmol/kg to 0.83cmol/kg. Similarly the mean surface and subsurface soil value of exchangeable Potassium (K^{+}) was 0.02cmol/kg to 0.04cmol/kg in Emeabiam, while Ohaji Egbema mean values ranged from 1.48cmol/kg to 3.10cmol/kg. Ohaji Egbema had high values in all the Pedons. Oguta mean values ranged from 0.23cmol/kg to1.33 cmol/kg, pedon one of Oguta had high value of potassium while pedon 2 and 3 were low.

Mean Sodium (Na^{+}) values for surface and subsurface horizons ranged from 0.03 cmol/kg to

0.05 cmol/kg, 1.09cmol/kg to 1.32cmol/kg, and1.11 to1.84cmol/kg for Emeabiam, Ohaji Egbema and Oguta respectively. Emeabiam pedons were very low in sodium while Ohaji Egbema and Oguta were high according to the ratings of FAO (2006).

Exchangeable (H^{+}) of Emeabiam soils had mean value of 1.02cmol/kg, 0.75cmol/kg and 0.70cmol/kg in pedon 1,2 and 3 and was rated moderate for both surface and subsurface soil. Similarly that of Ohaji Egbema was 0.68cmol/kg, 1.02cmol/kg and 1.23cmol/kg in pedons 1, 2 and 3 respectively and was rated low in pedon 1 and moderate in pedons 2 and 3. Also Oguta had mean values of 0.29cmol/kg, 0.33cmol/kg and 0.29 cmol/kg in pedon 1,2 and 3 respectively andwasrated low in all the pedons.

Exchangeable (Al^{-1}) had mean values of 0.65cmol/kg, 0.32cmol/kg and 0.70 cmol/kg in pedon 1,2 and 3 of Emeabiam soilsand was low. Ohaji Egbema had mean of 1.02 cmol/kg, 0.75cmol/kg and 0.94cmol/kg which was moderate in pedon 1, low in pedon 2,while Oguta had trace in pedon 1, 0.18cmol/kg in pedon 2 Exchangeable Al^{3+} was not detected in Oguta soils in Pedon 1 and 2 and trace in pedon 3. In this study, hydrogen ions rather than Aluminium ions dominated the exchange acidity. This is largely in agreement with reports of Amalu (1998) that H^+, rather than AL^{3+} dominates in majority of soils with pH less than 5 units. The value of exchangeable Al obtained for this study may not result to Al toxicity to crop. This agrees with Amberger(2006) who indicated that a concentration of Aluminum ion greater than one (>1cmol/kg) in the soil solution could lead to Aluminum toxicity. Similarly, the value of exchangeable H^+ obtained for this study will not be detrimental to crop growth. Total exchangeable acidity mean values ranged from 1.06cmol/kg to 1.68cmol/kg in Emeabiam. Ohaji Egbema mean ranged from 1.70cmol/kg to 2.17cmol/kg while Oguta mean ranged from 0.29cmol/kg to 0.36cmol/kg.

The total exchangeable bases (TEB) is the sum of all the exchangeable cations (Ca^{2+}, Mg^{2+}, Na^+ and $K^{+)}$. Emeabiam had 0.00, for Ohaji Egbema TEB ranged from 5.41cmol/kg to7.05cmol/kg and Oguta mean rangedfrom3.37 cmol/kg to 4.61cmol/kg andwas rated low in surface and subsurface area.

Similarly ECEC of Emebiam soils mean values ranged from 1.06cmol/kg to 1.68cmol/kg. Ohaji Egbema ranged from 7.11cmol/kg to 8.83cmol/kg while Oguta mean values ranged from 3.66cmol/kg to 4.90cmol/kg. All the locations were low for both surface and subsurface soil. It has been reported that the soils of South Eastern Nigeria have low ECEC and basic cations (Ogban *et al* 2011). The low ECEC have been attributed to the fact that soils in this region are strongly weathered, have little or no content of weathered materials in sand and silt fractions and have little or no content of weathered materials in sand and silt fractions and have predominantly kaolinite in their clay fractions. This finding is also in agreement with that of Akpan *et al* (2017) who worked on wetland soil in Calabar and observed low ECEC. Although ECEC was low in all the soils, Emebiam had the lowest value, compared to Oguta and Ohaji Egbema.

Mean base saturation (BS) values ranged from 63% to 82.6%,74% to 83%, and 89% to 93% for Emeabiam, Ohaji Egbema and Oguta respectively.All the locations had high base saturation. Oguta floodplain soil had the highest BS than that of Ohaji Egbema and Emebiam. (Akpan, Aki, and Isong, 2017) also obtained high base saturation for wetland soil.

Table 4.3a: Chemical Properties of Emeabiam Soils

Location/ Horizon	Depth cm	pH IN WATER (1:2.5)	OC %	OM %	N %	AP (mg/kg)	Ca	Mg cmol/kg	Na	K	Exch. H	Exch. Al	TEA Cmol/kg	TEB	ECEC	BS %
								Pedon 1								
EWS Ap	0-12	5.39	0.88	1.51	0.13	4.96	2.96	1.80	0.04	0.03	1.36	0.87	2.23	0.00	2.23	68.40
EWS AB	12-31	5.47	0.60	1.03	0.10	3.20	2.07	0.94	0.02	0.02	1.20	0.67	1.87	0.00	1.87	61.90
EWS BA	31-66	5.49	0.37	0.65	0.10	3.08	1.89	0.72	0.03	0.02	0.97	0.55	1.53	0.00	1.53	63.50
EWS Bt1	66-135	5.71	0.28	0.48	0.06	2.94	1.64	0.58	0.02	0.02	0.87	0.65	1.52	0.00	1.52	59.70
EWS Bt2	135-200	5.68	0.17	0.29	0.03	3.10	1.59	0.49	0.02	0.02	0.72	0.51	1.23	0.00	1.23	63.20
Mean		**5.55**	**0.46**	**0.79**	**0.08**	**3.46**	**2.03**	**0.91**	**0.03**	**0.02**	**1.03**	**0.65**	**1.68**	**0.00**	**1.68**	**63.34**
CV		**2.52**	**61.40**	**61.38**	**46.05**	**24.48**	**27.34**	**58.26**	**20.92**	**0.01**	**24.94**	**21.49**	**22.9**	**36.9**	**31.4**	**5.1**
								Pedon 2								
EWS Ap	0-8	6.49	1.54	3.17	0.22	13.49	4.51	2.34	0.07	0.05	0.80	0.34	1.14	0.00	1.14	85.90
EWS A	8-24	6.30	0.75	1.29	0.13	10.40	3.19	1.45	0.04	0.04	0.74	0.34	1.08	0.00	1.08	81.40
EWS AB	24-32	6.18	0.42	0.72	0.05	8.34	2.85	1.08	0.04	0.03	0.70	0.27	0.97	0.00	0.97	80.50
Mean		**6.32**	**0.90**	**1.73**	**0.13**	**10.74**	**3.52**	**1.62**	**0.05**	**0.04**	**0.75**	**0.32**	**1.06**	**0.00**	**1.06**	**82.7**
CV		**2.50**	**64.04**	**74.38**	**63.76**	**24.13**	**24.95**	**39.90**	**29.25**	**29.93**	**6.87**	**12.54**	**8.1**	**29.6**	**25.8**	**3.5**
								Pedon 3								
EWS Ap	0-6	5.88	0.91	1.58	0.14	5.41	3.16	1.94	0.04	0.04	0.88	0.84	1.72	0.00	1.72	84.30
EWS A	6-18	5.65	0.64	1.11	0.10	4.16	2.79	1.60	0.03	0.03	0.78	0.91	1.69	0.00	1.69	72.50
EWS AB	18-46	5.79	0.47	0.81	0.06	3.80	2.40	0.89	0.04	0.03	0.60	0.65	1.25	0.00	1.25	72.90
EWS BA	46-98	5.57	0.32	0.55	0.04	3.94	2.48	0.76	0.03	0.02	0.54	0.40	0.94	0.00	0.94	77.80
Mean		**5.72**	**0.59**	**1.01**	**0.08**	**4.33**	**2.71**	**1.30**	**0.03**	**0.03**	**0.70**	**0.70**	**1.40**	**0.00**	**1.40**	**76.88**
CV		**2.43**	**43.44**	**43.45**	**49.44**	**17.02**	**12.76**	**43.58**	**23.05**	**16.51**	**22.28**	**32.95**	26.80	22.50	23.20	7.20

OC – Organic Carbon, OM – Organic Matter, N – Nitrogen, AP – Available Phosphorus
CA – Calcium, Mg – Magnesium, Na – Sodium, K – Potassium, TEA – Total Exchangeable Acidity,
TEC – Total Exchangeable Bases, ECEC – Effective Cation Exchange Capacity, BS – Base Saturation,
Exch. H – Exchangeable Hydrogen, Exch. Al – Exchangeable Aluminum

TABLE 4.3B:Chemical Properties of OhajiEgbema Soils

Location	Depth cm	pH(H_2O)	OC %	OM %	N %	AP Mg/kg	Ca	Mg Cmol/kg	K	Na	Exch H	Exch. Al Cmol/kg	TEA	TEB	ECEC	BS %
								Pedon 1								
EGBE Ap	0-13	5.95	0.88	1.51	0.13	4.83	2.30	1.50	2.2	0.88	0.77	0.38	1.15	6.88	8.03	85.70
EGBE A	13-34	6.13	0.64	1.10	0.10	6.09	1.40	0.76	1.47	1.30	0.64	0.37	1.00	4.93	5.93	83.10
EGBE AB	34-60	6.24	0.50	0.86	0.07	3.57	2.90	1.00	1.14	1.24	0.72	3.53	4.25	6.28	10.53	83.60
EGBE Bt1	60-85	6.12	0.60	1.03	0.12	5.74	2.00	0.70	1.25	1.09	0.80	0.52	1.32	5.04	6.36	79.20
EGBE Bt2	85-200	6.26	0.01	0.17	0.02	3.99	1.00	0.67	1.33	0.93	0.48	0.30	0.79	3.93	4.72	83.40
Mean		**6.14**	**0.53**	**0.93**	**0.09**	**4.84**	**1.92**	**0.93**	**1.48**	**1.09**	**0.68**	**1.02**	**1.70**	**5.41**	**7.11**	**83.00**
CV		**2.01**	**60.91**	**52.35**	**48.82**	**22.40**	**38.87**	**37.37**	**28.5**	**16.97**	**18.64**	**137.80**	**84.60**	**21.60**	**31.60**	**2.80**
								Pedon 2								
EGBEAp	0-9	5.97	1.76	3.03	0.19	6.37	2.30	1.62	5.33	1.67	0.89	0.67	1.55	7.00	8.55	81.90
EGBE A	9-28	6.07	0.42	3.72	0.08	3.92	2.20	1.40	4.3	1.57	0.90	0.67	1.57	9.47	11.04	85.80
EGBE BA	28-50	6.80	0.16	0.28	0.03	3.57	2.50	0.95	1.14	0.77	0.69	0.42	1.10	5.36	6.46	82.90
EGBEBt1	50-90	6.24	0.22	0.38	0.03	4.83	2.50	0.80	1.5	0.95	1.20	1.00	2.20	5.75	7.95	72.30
EGBE Bt2	90-200	6.04	0.20	0.34	0.03	4.41	1.20	1.90	3.21	1.35	1.42	1.07	2.49	7.66	10.15	75.50
Mean		**6.22**	**0.55**	**1.55**	**0.07**	**4.62**	**2.14**	**1.33**	**3.10**	**1.26**	**1.02**	**0.76**	**1.78**	**7.05**	**8.83**	**79.68**
CV		**5.41**	**123.60**	**108.70**	**97.25**	**23.57**	**25.29**	**34.33**	**57.8**	**30.91**	**28.51**	**35.04**	**31.20**	**23.30**	**20.50**	**7.00**
								Pedon 3								
EGBEAp	6-9	5.74	2.04	3.51	0.22	8.47	2.00	0.82	3.55	1.44	0.95	0.59	1.54	6.99	8.53	81.90
EGBE A	9-26	5.83	0.58	1.00	0.10	10.99	1.50	1.00	1.31	1.22	1.09	0.75	1.84	5.03	6.86	73.30
EGBE BA	26-46	5.84	0.40	0.69	0.06	4.55	2.60	1.00	1.39	1.24	1.17	0.87	2.04	6.23	8.27	75.30
EGBE Bt1	46-67	5.83	0.56	0.96	0.07	4.90	1.50	1.00	2.37	1.13	1.32	1.04	2.35	6.00	8.35	71.90
EGBE Bt2	67-150	5.50	0.26	0.45	0.04	5.11	3.00	1.20	2.16	1.56	1.64	1.45	3.09	7.92	11.01	71.90
Mean		**5.74**	**0.77**	**0.94**	**0.10**	**6.80**	**2.12**	**1.00**	**2.16**	**1.32**	**1.23**	**0.94**	**2.17**	**6.43**	**8.60**	**74.86**
CV		**2.51**	**94.11**	**94.13**	**71.18**	**41.49**	**31.54**	**13.39**	**42.1**	**13.38**	**21.28**	**35.29**	**27.30**	**16.90**	**17.40**	**5.60**

CV = Coefficient of Variation, Egbe - EgbemaOC – Organic Carbon, OM – Organic Matter, N – Nitrogen, AP – Available Phosphorus, CA – Calcium, Mg – Magnesium, Na – Sodium, K – Potassium, TEA – Total Exchangeable Acidity, TEC – Total Exchangeable Bases, ECEC – Effective Cation Exchange Capacity, BS – Base Saturation, Exch. H – Exchangeable Hydrogen, Exch. Al – Exchangeable Aluminum

Table 4.3C: Chemical Properties of Oguta Soils

Location	Depth	pH(H_2O)	OC %	OM %	TN %	AP Mg/kg	Ca ←	Mg Cmol/kg	K	Na →	Exch.H ←	Exch.AL Cmol/kg	TEA	TEB	ECEC →	BS(%)
								Pedon 1								
OGU A	0-10	5.62	0.70	1.30	0.13	4.97	1.23	0.63	2.99	2.51	0.37	TRACE	0.37	7.36	7.73	95.20
OGU BA	10-47	6.05	0.46	0.79	0.11	4.41	1.60	0.50	0.90	2.01	0.30	TRACE	0.30	5.01	5.31	94.30
OGU Bt1	47-82	6.94	0.20	0.34	0.04	3.78	1.58	0.67	0.28	0.74	0.35	TRACE	0.35	3.27	3.62	90.30
OGU Bt2	82-136	6.23	0.160	0.28	0.03	4.13	1.50	0.50	2.36	2.27	0.25	TRACE	0.25	4.63	4.88	94.90
OGU Bt3	136-200	6.54	0.34	0.59	0.07	4.13	0.80	0.20	0.11	1.66	0.200	TRACE	0.20	2.77	2.97	93.30
Mean		**6.28**	**0.42**	**0.66**	**0.08**	**4.28**	**1.34**	**0.5**	**1.33**	**1.84**	**0.29**		**0.29**	**4.61**	**4.90**	**93.60**
CV		**7.94**	**58.63**	**62.75**	**58.16**	**10.36**	**25.12**	**36.85**	**96.67**	**37.55**	**23.63**		**23.60**	**39.00**	**37.50**	**2.10**
								Pedon 2								
OGU A	0-12	5.63	0.50	0.860	0.11	5.25	0.90	0.80	0.26	0.29	0.47	0.18	0.65	2.25	2.90	77.50
OGU BA	12-53	6.23	3.38	0.65	0.08	4.20	1.15	0.45	0.13	1.66	0.37	TRACE	0.37	3.39	3.76	90.20
OGU Bt1	53-75	6.55	0.30	0.52	0.05	3.57	1.34	0.46	0.47	1.23	0.33	TRACE	0.33	3.50	3.83	91.40
OGU Bt2	75-112	6.60	0.120	0.21	0.03	3.92	1.40	0.50	0.10	3.30	0.251	TRACE	0.25	5.30	5.55	95.50
OGU Bt3	112-200	6.57	0.220	0.38	0.04	4.06	1.20	0.65	0.21	0.86	0.217	TRACE	0.22	2.92	3.14	92.90
Mean		**6.32**	**0.90**	**0.52**	**0.06**	**4.20**	**1.20**	**0.57**	**0.23**	**1.50**	**0.33**	**0.18**	**0.36**	**3.47**	**3.84**	**89.50**
CV		**6.52**	**154.00**	**48.04**	**56.06**	**15.05**	**16.28**	**26.32**	**62.56**	**77.72**	**30.32**		**47.20**	**32.70**	**27.10**	**7.80**
								Pedon 3								
OGU A	0-10	6.65	0.24	0.41	0.04	5.53	0.80	0.25	0.67	1.42	0.334	TRACE	0.33	3.14	3.47	90.40
OGU BA	10-36	5.48	0.24	0.41	0.04	3.92	1.10	1.40	0.10	0.33	0.284	TRACE	0.28	2.93	3.21	91.20
OGUBt1	36-78	6.14	0.10	0.17	0.02	4.27	1.30	0.70	0.11	0.26	0.25	TRACE	0.25	2.37	2.62	90.50
OGU Bt2	78-126	6.11	0.30	0.52	0.05	4.90	1.20	1.50	0.80	1.73	0.30	TRACE	0.30	5.23	5.53	94.60
OGU Bt3	126-200	6.86	0.20	0.34	0.04	4.48	0.90	0.30	0.16	1.80	0.32	TRACE	0.32	3.16	3.48	90.80
Mean		**6.25**	**0.22**	**0.37**	**0.04**	**4.62**	**1.06**	**0.83**	**0.37**	**1.11**	**0.29**		**0.30**	**3.37**	**3.66**	**91.50**
CV		**8.61**	**34.02**	**34.27**	**31.31**	**13.42**	**19.56**	**71.48**	**92.10**	**68.25**	**10.85**		**10.90**	**32.40**	**30.10**	**1.90**

OGU- Oguta

OC – Organic Carbon, OM – Organic Matter, N – Nitrogen, AP – Available Phosphorus, CA – Calcium, Mg – Magnesium,
Na – Sodium, K – Potassium, TEA – Total Exchangeable Acidity,TEC – Total Exchangeable Bases, ECEC – Effective Cation Exchange Capacity,
BS – Base Saturation, Exch. H – Exchangeable Hydrogen, Exch. Al – Exchangeable Aluminu

4.4 Nitrogen Forms of Studied Areas.

The nitrogen forms of studied locations are presented in Tables 4.4a, 4.4b,and 4.4c. The high TN indicates high amount of organic matter deposit and high rate of mineralization. This is contrary to the findings of Ahukaemere *et al* (2015) which stated that low nitrogen concentration is a common phenomenon in the soils of South Eastern Nigeria.Variation in total nitrogen distribution with varying soil depth has been widely reported (Onweremadu, Okuwa, Njoku, and Ufot, 2011; Zhijing *et al* 2013). The A-horizon contains more total nitrogen over other horizons which showed that mineralization is higher in the surface horizons of the studied pedons. Decrease in total nitrogen content with increased soil depth has been reported (Zhijing *et al* 2013).The range was between 290 and 1280 mg/kg, 490 and 2190 mg/kg, and 440 and 1360 mg/kg in Emeabiam for pedons 1,2 and 3respectively. The mean values were 836,1333and 842.5Mg/kg for Emeabiam pedon 1,2 and 3 respectively. The highest amount of TN occurred on the surface horizon of pedon 2. TN was high in all the pedons respectively in Pedon 1, 2 and 3 of Emeabiam floodplain soils. Total nitrogen also had high variation ≥46.05 ≤63 in all the Pedons.

TN content of Ohaji Egbema soils ranged from 200mg/kg to 1360mg/kg with a mean of 890mg/kg in pedon 1, pedon 2 ranged from 270mg/kg to 1880mg/kg with a mean of 710mg/kg while pedon 3 ranged from 400mg/kg to 2180mg/kg with a mean of 988mg/kg. TN is also high in all the floodplain soils of Ohaji Egbema. Increased total nitrogen fixation by crops with organic matter content have been reported by Gebrelibanos and Assen (2013), Moges,

Dagmachew and Yimer(2013), Mubyana and Masamba (2014). According to Moges *et al* (2013) the direct relationship of Total N with organic matter has been attributed to binding of most soil N with organic carbon.Others have reported TN means of 90-98% (Meysner, Szajdak and Ku 2006, Sabiene, Kusliene, and Zaleckas, 2010). Total nitrogen had high variation ≥40.49 ≤97.25 in all the Pedons.

TN content of Oguta soils ranged from 340mg/kg to 1340mg/kg with a mean of 758mg/kg in pedon 1.Pedon2 ranged from 250mg/kg to 1140mg/kg with a mean of 630mg/kg while pedon 3 ranged from 180mg/kg to 430mg/kg with a mean of 366 mg/kg. Oguta pedon, 1 and 2 had high TN while pedon 3 had moderate TN. The high TN indicates high amount of organic matter deposit and high rate of mineralization. Variation in total nitrogen distribution with soil profile depth has been widely reported (Onweremadu *et al* 2011; Zhijing *et al* 2013). The A-horizon contains more total nitrogen than other horizons which showed that mineralization is higher in the surface horizons of the studied area.Among the three locations studied the mean values showed that the highest value occurred in Emeabiam soils and the lowest was in Oguta pedons. Total nitrogen also had high variation ≥ 31.31 % ≤ 58.16 % in all the Pedons.

Total Organic Nitrogen (TON) content of soils of Emeabiam ranged from 258.1mg/kg to 960mg/kg with a mean of 680.86mg/kgin pedon 1. Pedon 2 ranged from 455.7mg/kg to 2002.6mg/kg with a mean of 1193.73mg/kg, while pedon 3 ranged from 400mg/kg to 1142.4 mg/kg with a mean of 742.58mg/kg. The mean values indicated high organic nitrogen in all the pedons. The high content of organic nitrogen in soils of Emeabiam could be attributed to high amount of organic matter and high mineralization.Total Organic nitrogen also had high variation ≥41.43% ≤65% in all the Pedons.

TON content of Ohaji Egbema soils ranged from 178mg/kg to 1171.8mg/kg with a mean of 810.8mg/kg in pedon 1. Pedon 2 ranged from 237.6mg/kg to 1394.2mg/kg with a mean of 568.8mg/kg, while pedon 3 ranged from 340.8mg/kg to 1727.2mg/kg with a mean of 826.82mg/kg. The high Total organic nitrogen (TON)of all the pedons could be as a result of high amount of organic matter deposit and rate of decomposition/mineralization. Total Organic nitrogen had high variation ≥ 49.43% ≤ 87.34% in all the Pedons.

TON content of Oguta soils ranged from 290mg/kg to 1234.8mg/kgwith a mean of 692.82mg/kg. In pedon 1.Pedon2 ranged from 195mg/kg to 1037.4mg/kg with a mean of 561.92mg/kg while pedon 3 ranged from 136.2mg/kg to 422.4mg/kg with a mean of 320.48mg/kg. The highestTON of Oguta occurred in pedon 1. The values were moderate in pedon 2 and pedon 3. Among the three locations the mean values showed that the highest amount of organic nitrogen occurred in Emeabiam and the lowest was in Oguta. Total Organic nitrogen also had high variation ≥34.9 % ≤ 58.93% in all the Pedons.

Ammonium Nitrogen (NH_4N) content of Emeabiam soils ranged from 16mg/kg to 189.9mg/kg with a mean of 89.4 mg/kg in pedon 1. Pedon 2 ranged from 18mg/kg to 101.1mg/kg with a mean of 69.60mg/kg while pedon 3 ranged from 20.2mg/kg to 116.6mg/kg with a mean of 56.78mg/kg. Ammonium nitrogen concentration was highest at the surface horizons. The high ammonium nitrogen in all the pedons may be attributed to high mineralization as suggested by Gebrelibanois and Assen (2013), volatilization and intense rainfall. Ammonium nitrogen also had high variation ≥64.73% ≤ 80.75% inall the Pedons.

Ammonium Nitrogen (NH_4^+-N) content of Ohaji Egbema soils ranged from 10.5mg/kg to 48.5mg/kg with a mean of 30.4mg/kg in pedon1. Pedon 2 ranged from13.3mg/kg to 211.9mg/kg with a mean of 67.66mg/kg, while pedon 3 ranged from 26.6mg/kg to 250mg/kg with a mean of 83.32mg/kg. Increased concentration down the soil depth has been reported and attributed to leaching losses. (Yang *et al*; 2004). The values showed that all the pedons had high NH_4^+-N and above the critical limit. Ammounium concentration above 10 mg/kg is not good for crop production (Marx, Hart and Stevens, 1999). Ammonium nitrogen had high variation ≥ 46.15 % ≤ 113.7 % in all the Pedons.

Ammonium Nitrogen (NH_4N) content of Oguta soils ranged from 16mg/kg to 60.3mg/kg with a mean of 35.7 mg/kg in pedon 1.Pedon2 ranged from 19.9mg/kg to 50.6mg/kg with a mean of 36.02mg/kg while pedon 3 ranged from 22.2mg/kg to 30.6mg/kg with a mean 24.78mg/kg. it has been reported that increased concentration down the soil depth could be attributed to leaching losses (Yang*et al;* 2004). There is no distinct pattern of N distribution with depth but with the highest concentration associated with 10-30 cm soil depth (Zhijing *et al;* 2013). The mean values showed that the amount of ammonium nitrogen in the soils werehigh and will not besuitable for crop production. The three locations studied were all high in ammonium nitrogen. Ammonium nitrogen had low to high variation ≥ 14.39 % ≤ 49.75 % in Oguta soils.

Nitrite nitrogen (NO_2-N) content of Emeabiam soils ranged from 5.7mg/kg to 40.8mg/kg with a mean of 21.34mg/kg in pedon1, pedon 2 ranged from 4.4mg/kgto 36.4mg/kg with a mean of 21.40mg/kg while pedon 3 ranged from 4.8mg/kg to 35.6mg/kg with a mean of 13.58mg/kg.Nitrite nitrogen had high variation ≥ 75.2 % ≤ 108.7 % in all the Pedons.

Nitrite nitrogen (NO_2-N) content of Ohaji Egbema soils ranged from 3.2mg/kg to 11.8mg/kg with a mean of 8.02mg/kg in pedon 1. Pedon 2 ranged from 4mg/kg to 69.9 mg/kg with a mean of 18.96mg/kg while pedon 3 ranged from 6.1mg/kg to 45.7mg/kg with a mean of 20.92mg/kg. Nitrite nitrogen had high variation ≥ 38.63 % ≤ 151.2 % in all the Pedons.

Nitrite nitrogen (NO_2-N) content of Oguta soils ranged from 2mg/kg to 15.2mg/kg with a mean of 7.76 mg/kg in pedon1. Pedon 2 ranged from 3.5mg/kg to 10 .75mg/kg with a mean of 7.39mg/kg while pedon 3 ranged from 3.9mg/kg to 11.11mg/kg with a mean of 7.13mg/kg.Nitrite nitrogen had high variation ≥ 38.1 % ≤ 64.02 % in all the Pedons.

Nitrate nitrogen (NO_3^--N) content of Emeabiam soils ranged from 9.9mg/kg to 80.3mg/kg with a mean of 38.74 mg/kg in pedon 1. Pedon 2 ranged from 11.2mg/kg to 60.0mg/kg with a mean of 40.37mg/kg while pedon 3 ranged from 12.3mg/kg to 59.8mg/kg with a mean of 26.98mg/kg. The mean values showed that nitrate had high values and the values were above the critical limit suitable for crop production. The concentration of NO_3-N decreased with increasing soil depth probably due to the high organic matter content on the surface soil (Yang, Hang, Tang and Han 2014). The level of NO_3-N has been indicated and ascribed to changes in rates of organic nitrogen mineralization and losses due to plant and microbial uptake, leaching, runoff and erosion (Yang *et al* 2004). Nitrate nitrogen had high variation ≥ 63.81% ≤ 81.71 % in all the Pedons.

Nitrate nitrogen (NO_3^--N) content of Ohaji Egbema soils ranged from 6.5mg/kg to 27.8mg/kg with a mean of 17.44 mg/kg in pedon 1. Pedon 2 ranged from 9.1mg/kg to 144.3mg/kg with a mean of 40.76mg/kg while pedon 3 ranged from 18.6mg/kg to 150.8mg/kg with a mean of 53.06mg/kg. The level of nitrate in pedon 1 of Ohaji Egbema soils was moderate and adequate for crop production, while pedon 2 and 3 had high nitrate level that are above the critical limit. Nitrate nitrogen had high variation ≥ 45.63 % ≤ 105.9 % in all the Pedons.

Nitrate nitrogen (NO_3-N) content of Oguta soils ranged from 4.8mg/kg to 30.9mg/kg with a mean of 17.06mg/kg in pedon 1. Pedon 2 ranged from 7.3mg/kg to 27.7 mg/kg with a mean of

17.82mg/kg while pedon 3 ranged from 9.2mg/kg to 14.3mg/kg with a mean of 11.24mg/kg. The nitrate of Oguta soil was moderate showing that it will be good for crop production. The moderate amount of NO_3-N in Oguta soils may be attributed to volatilization due to intense temperature, low mineralization and high immobilization by microorganism removal through animal grazing. This is consistent with the findings of Brady and Weil (2002) and Jandl, Alewell, and Prietzel (2004). The mean values of the three locations showed that Oguta soils had better nitrate nitrogen suitable for crop production than Emeabiam and Ohaji Egbema. Nitrate nitrogen had moderate to high variation ≥ 19.29 % ≤ 73.94 % .

Total Inorganic nitrogen (TIN)content of Emeabiam soils ranged from 31.6mg/kg to 310.1mg/kg with a mean of 149.3mg/kg in pedon 1.Pedon2 ranged from 33.6mg/kg to 187.4mg/kg with a mean of 131.47mg/kg while pedon 3 ranged from 38.1mg/kg to 212mg/kg with a mean of 97.33mg/kg. The mean value was above critical limit for tropical soil (Enwezor, Ohiri, Opowaribo, and Udo, 1990). Total Inorganic nitrogen had high variation ≥ 64.69 % ≤ 80.23 % in all the Pedons.

Total Inorganic nitrogen (TIN)content of Ohaji Egbema soils ranged from 20.2mg/kg to 85.2mg/kg with a mean of 55.86mg/kg in pedon 1, pedon 2 ranged from 27.3mg/kg to 426.12mg/kg with a mean of 127.38mg/kg while pedon 3 ranged from 53.1mg/kg to 446.5mg/kg with the mean of 157.20mg/kg. Total Inorganic nitrogen had high variation ≥ 43.17 % ≤ 105.7 % in all the Pedons.

Total Inorganic nitrogen (TIN)content of Oguta soils ranged from 22.8mg/kg to 100.5mg/kg. with a mean of 60.52mg/kg in pedon 1, pedon 2 ranged from 31.2mg/kg to 88.5mg/kg with a mean of 61.23mg/kg while pedon 3 ranged from 36.8mg/kg to 56.01mg/kg with a mean of 43.15mg/kg. Total Inorganic nitrogen had moderate to high variation ≥ 17.21 % ≤ 55.91 % in all the Pedons.

Table 4.4a: Nitrogen Forms at Emebiam StudiedLocations

Horizons	Depth cm	TN	TO N	$NH_4 – N$ Mg/kg	$N0_2 – N$	$N0_3 – N$	TIN
				EWS Pedon 1			
Ap	0-12	1280	960	189.9	40.8	80.3	310.1
AB	12-31	980	739.2	130.8	36.5	60.5	227.8
BA	31-66	1010	888.8	80.6	12.9	25.6	119.1
Bt1	66-135	620	558.2	29.7	10.8	17.4	57.9
Bt2	135-200	290	258.1	16	5.7	9.9	31.6
Mean		**836**	**680.86**	**89.4**	**21.34**	**38.74**	**149.3**
CV		**46.05**	**41.43**	**80.75**	**75.39**	**78.09**	**78.64**
				Pedon 2			
OA	0-8	2190	2002.6	89.7	23.4	60	173.4
A	8-24	1320	1122.9	101.1	36.4	49.9	187.4
AB	24-32	490	455.7	18	4.4	11.2	33.6
Mean		**1333.33**	**1193.73**	**69.60**	**21.40**	**40.37**	**131.47**
CV		**63.76**	**65**	**64.73**	**75.2**	**63.81**	**64.69**
				Pedon 3			
OA	0-6	1360	1142.4	116.6	35.6	59.8	212
A	6-18	990	910.8	50.2	8.3	18	76.5
AB	18-46	580	516.3	40.1	4.8	17.8	62.7
BA	46-98	440	400.8	20.2	5.6	12.3	38.1
Mean		**842.5**	**742.58**	**56.78**	**13.58**	**26.98**	**97.33**
CV		**49.44**	**46.4**	**73.6**	**108.7**	**81.71**	**80.23**

EWS – Emeabiam Water Side, CV = Coefficient of Variation, TN = Total Nitrogen, TON = Total Organic Nitrogen, TIN = Total Inorganic Nitrogen
NH_4-N= Ammonium Nitrogen, NO_2-N= Nitrite Nitrogen, NO_3 –N= Nitrate Nitrogen

Table 4.4b Nitrogen Forms at Ohaji Egbema StudiedLocation

Horizons	DepthCm	TN	TON	NH4 - N	No_2 - N	No_3 - N	TI N
		←	Mg/Kg			→	
			Egbe Pedon 1				
Ap	0-13	1360	1171.8	48.5	8.9	27.8	85.2
A	13-34	1000	932.6	36.7	8.3	18.7	63.7
AB	34-60	730	678.9	25.5	7.9	13.6	47
Bt1	60-85	1160	1092.7	30.8	11.8	20.6	63.2
Bt2	85-200	200	178	10.5	3.2	6.5	20.2
Mean		**890**	**810.8**	**30.4**	**8.02**	**17.44**	**55.86**
CV		**50.49**	**49.43**	**46.15**	**38.63**	**45.63**	**43.17**
			Egbe Pedon 2				
Ap	0-9	1880	1394.2	211.9	69.9	144.3	426.12
A	9-28	800	680.8	72.7	11.9	30.1	114.7
BA	28-50	290	261.7	13.3	3.8	10.2	27.3
Bt1	50-90	270	237.6	16.6	4	10.1	30.7
Bt2	90-200	310	269.7	23.8	5.2	9.1	38.1
Mean		**710**	**568.8**	**67.66**	**18.96**	**40.76**	**127.38**
CV		**97.25**	**87.34**	**124.4**	**151.2**	**143.6**	**134.1**
			Egbe Pedon 3				
Ap	6-9	2180	1727.2	250	45.7	150.8	446.5
A	9-26	1030	875.9	69.9	28.8	50.8	148.98
BA	26-46	640	555.4	38.8	16.1	25.4	80.3
Bt1	46-67	690	634.8	26.6	7.9	18.6	53.1
Bt2	67-150	400	340.8	31.3	6.1	19.7	57.1
Mean		**988**	**826.82**	**83.32**	**20.92**	**53.06**	**157.20**
CV		**71.18**	**65.13**	**113.7**	**78.85**	**105.9**	**105.7**

EGBE= Egbema, CV = Coefficient of Variation, TN = Total Nitrogen,
TON = Total Organic Nitrogen, TIN = Total Inorganic Nitrogen,
NH_4-N= Ammonium Nitrogen, NO_2-N= Nitrite Nitrogen, NO_3 –N= Nitrate Nitrogen

Table4.4c: Nitrogen Forms at Oguta Studied Locations

Location/ Horizons	Depth cm	TN	TO N	$NH_4 - N$ Mg/kg	$NO_2 - N$	$NO_3 - N$	TIN
			OGU Pedon 1				
A	0-10	1340	1234.8	60.3	9.3	30.9	100.5
BA	10-47	1080	982.8	45.8	15.2	30.5	91.5
B1	47-82	370	346.8	16	2	4.8	22.8
B2	82-136	340	290	23	7.3	8.8	39.1
B3	136-200	660	609.7	33.4	5	10.3	48.7
Mean		**758**	**692.82**	**35.7**	**7.76**	**17.06**	**60.52**
CV		**58.16**	**58.93**	**49.75**	**64.02**	**73.94**	**55.91**
			Pedon 2				
A	0-12	1140	1037.4	50.6	10.2	27.7	88.5
BA	12-53	820	738	40.7	10.75	25.2	76.65
B1	53-75	530	461.6	38.8	8.5	10.7	58
B2	75-112	250	195	30.1	3.5	18.2	51.8
B3	112-200	410	377.6	19.9	4	7.3	31.2
Mean		**630**	**561.92**	**36.02**	**7.39**	**17.82**	**61.23**
CV		**56.06**	**58.74**	**32.17**	**46.41**	**49.69**	**36.36**
			Pedon 3				
A	0-10	430	387.2	25.8	6.61	9.2	41.61
BA	10-36	390	352.1	22.3	3.9	10.6	36.8
B1	36-78	180	136.2	22.2	5.8	12.6	40.6
B2	78-126	480	422.4	30.6	11.11	14.3	56.01
B3	126-200	350	304.5	23	8.21	9.5	40.71
Mean		**366**	**320.48**	**24.78**	**7.13**	**11.24**	**43.15**
CV		**31.31**	**34.9**	**14.39**	**38.1**	**19.29**	**17.21**

OGU – Oguta, CV = Coefficient of Variation, TN= Total Nitrogen, TON = Total Organic Nitrogen, TIN = Total Inorganic Nitrogen, NH_4-N= Ammonium Nitrogen, NO_2-N= Nitrite Nitrogen, NO_3 –N= Nitrate Nitrogen.

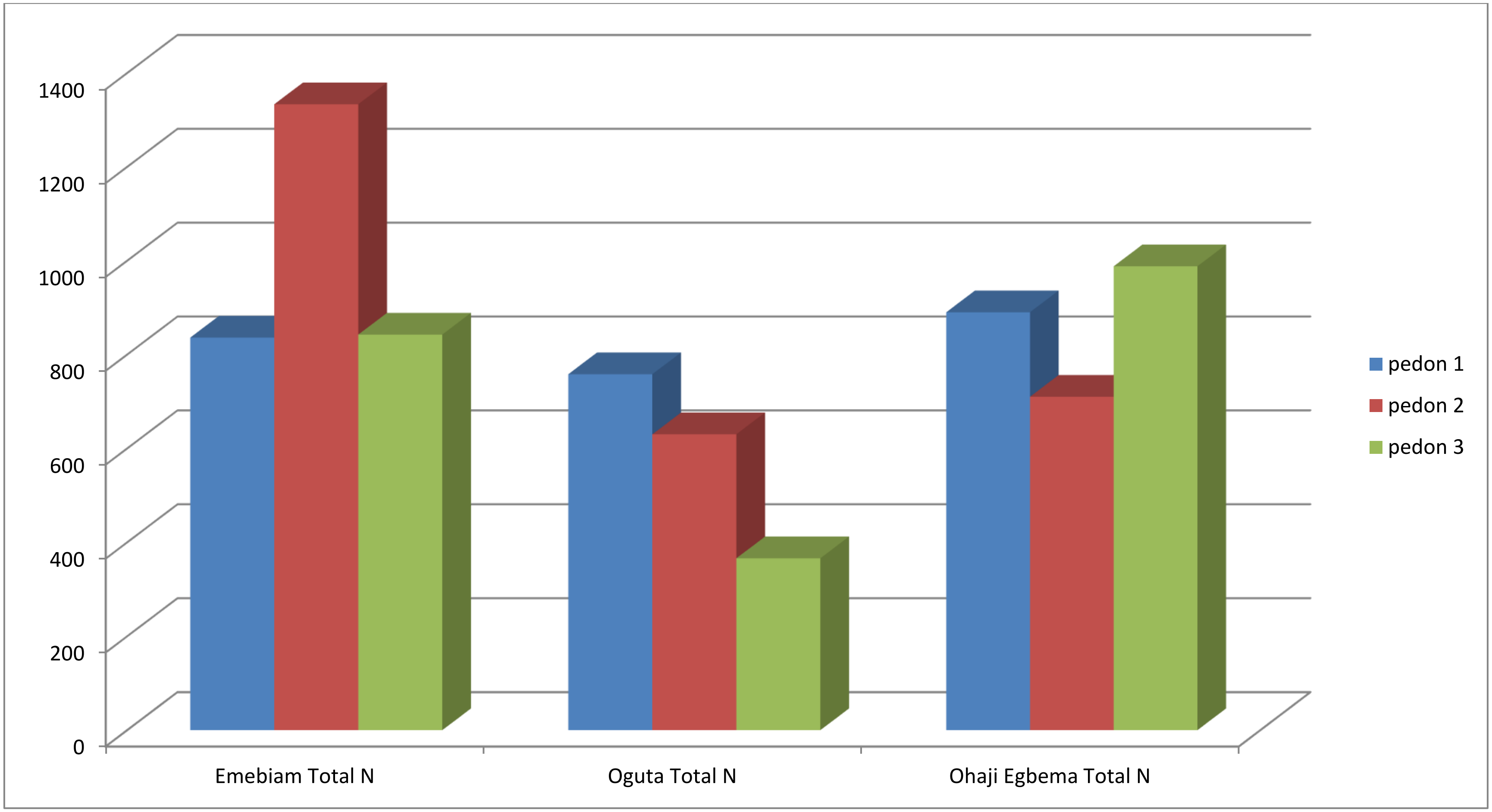

Figure 1. Total Nitrogen of Studied Locations.

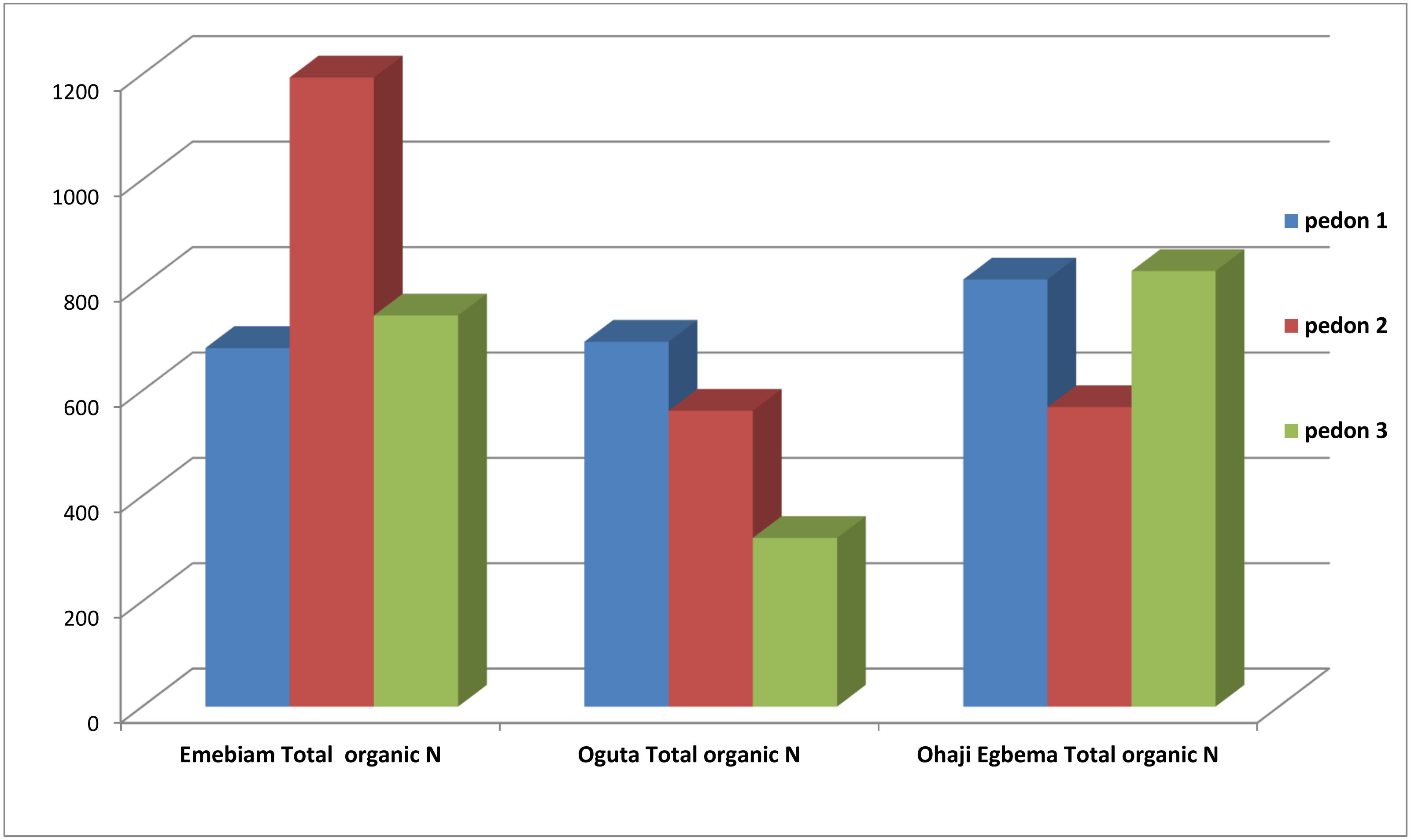

Figure 2. Total OrganicNitrogen of Studied Locations.

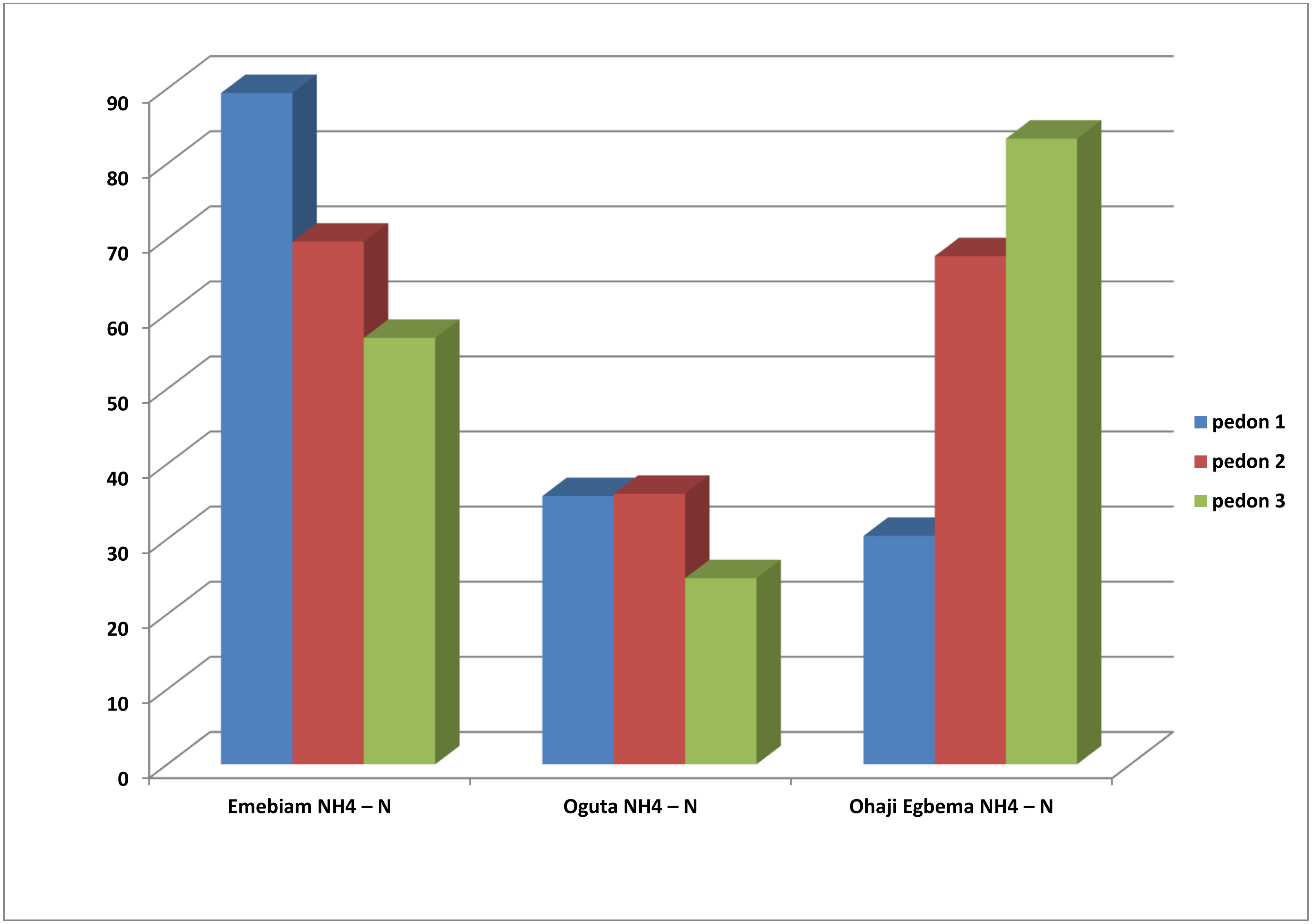

Figure 3. Ammonium Nitrogen of Studied Locations.

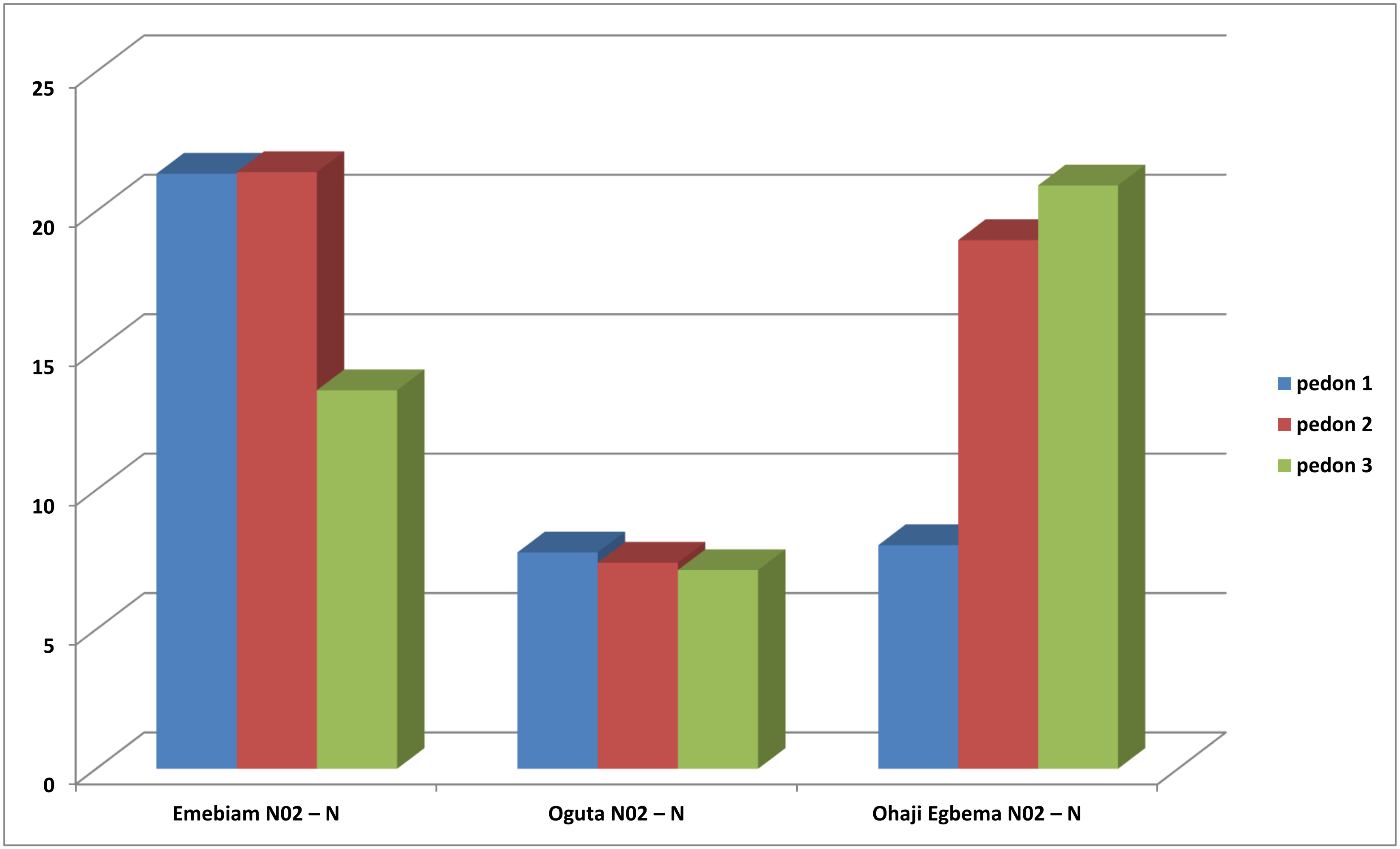

Figure 4. NitriteNitrogenof Studied Locations.

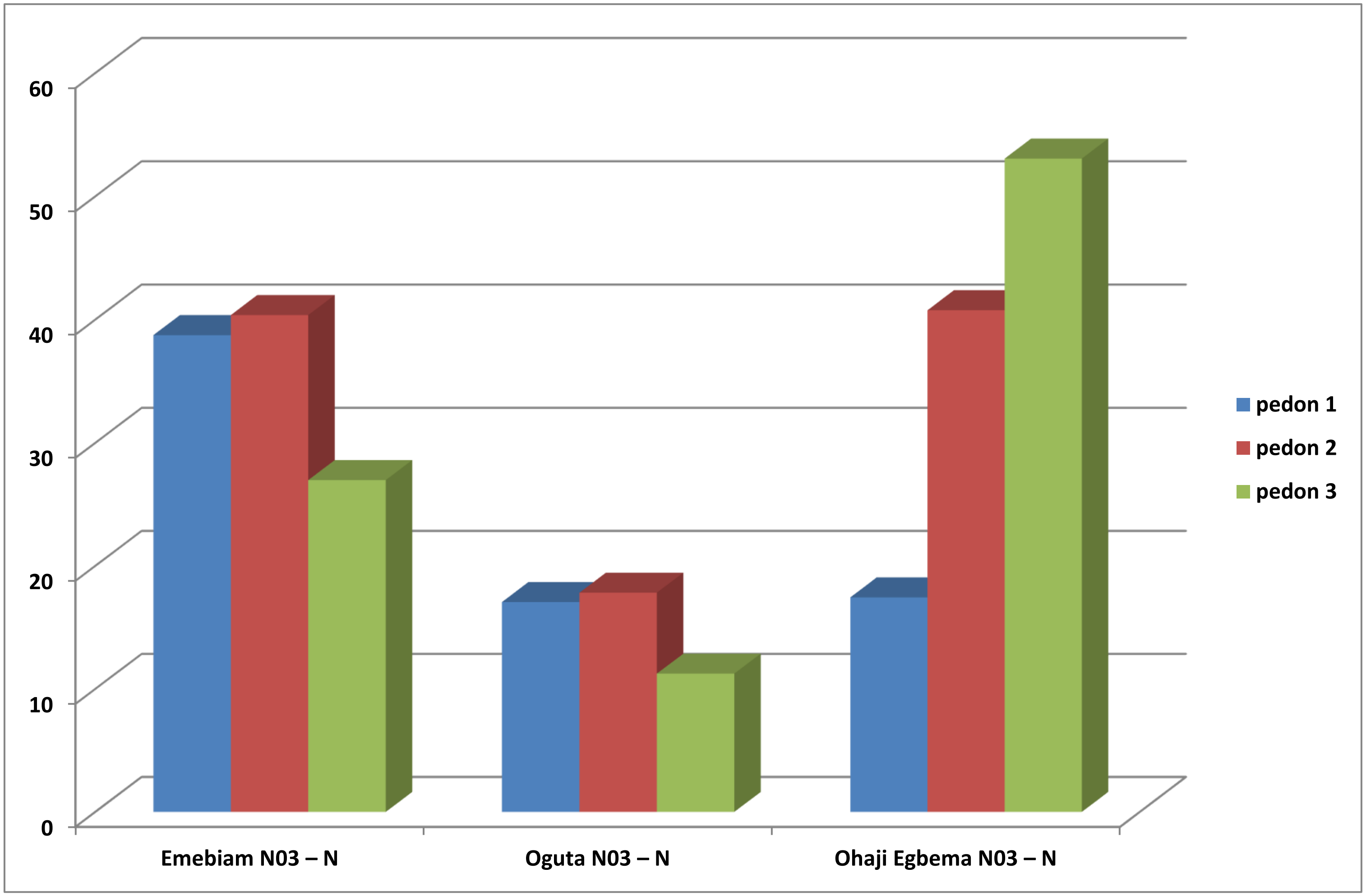

Figure 5. Nitrate Nitrogen of Studied Locations

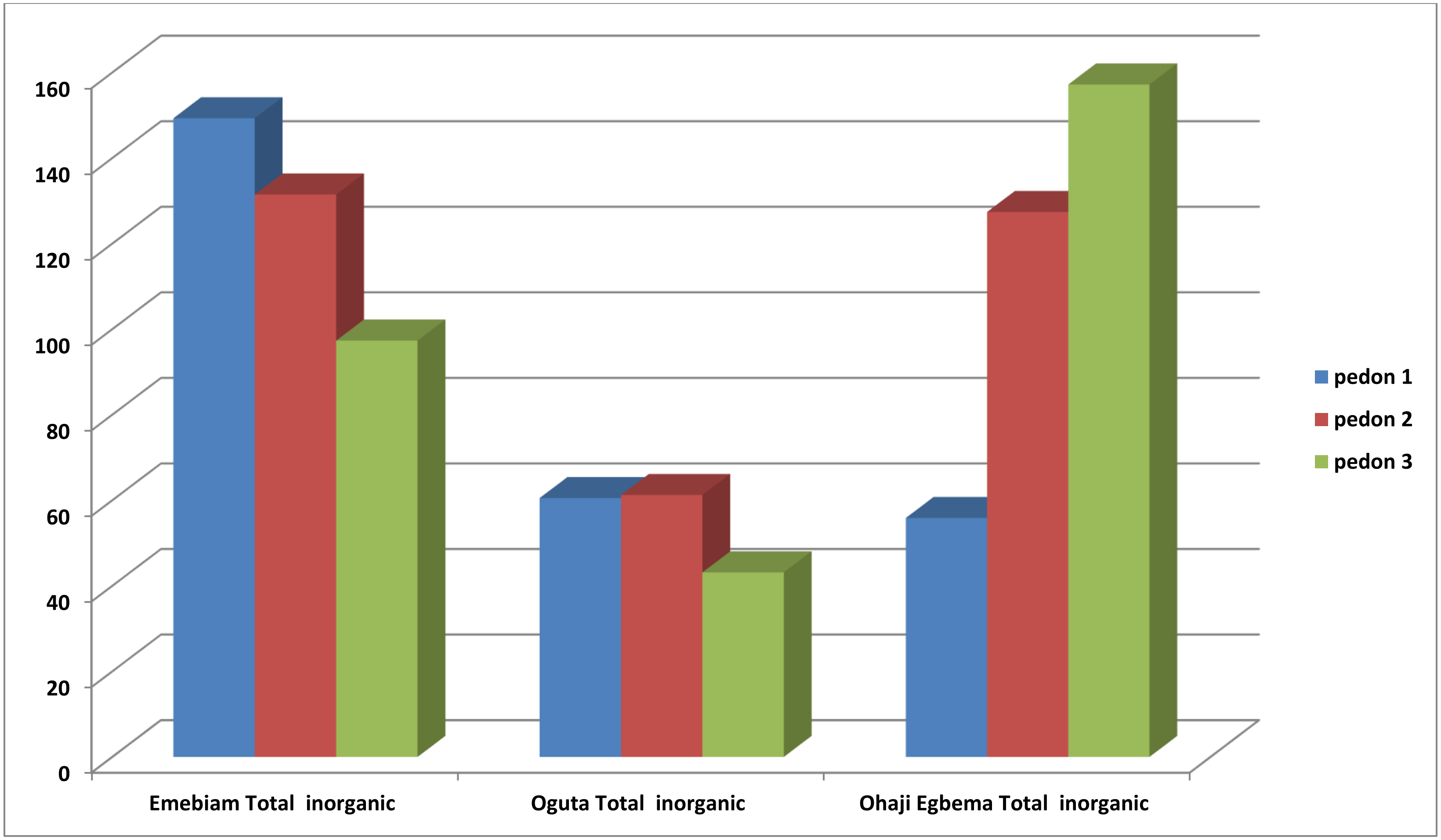

Figure 6. Total Inorganic Nitrogen of Studied Locations.

4.5. Relationship between Nitrogen Forms and Soil Properties.

Correlation coefficient of soils is shown in Table 4:5. From the results of correlation analysis Total inorganic N correlated negatively and significantly with clay (r=-0.71**) but positively correlated with organic carbon (r=0.64*), Effective cation exchange capacity ECEC (0.69*) and total exchange acidity (0.69*) in Emeabiam soil. Also total N correlated negatively and significantly with clay (r=-0.71**) and positively with organic carbon ((0.95**) sand (0.54*) and available phosphorous (0.69*) in Emeabiam soil. Total organic N follow similar trend with total nitrogen. Base saturation also correlated with total organic nitrogen. NH_4, NO_3, NO_2 followed similar trend with inorganic nitrogen. Nitrate correlated with sand also. All the forms of nitrogen correlated negatively with bulk density but no significant relationship.

NH_4-N (Ammonium Nitrogen) followed similar trend of significant correlation with NO_3-N. This result conformed to the findings of (Wang, Mou, and Huang, 2007) in Subtropical Forest of China. According to these researchers, the factors that affect NO_3-N also have greater potential to affect NH_4-N in soil, especially tropical soils. These relationships indicate the potential influence of one parameter over the other. The negative correlation implies that as one parameter increases the other decreases.. The resultshowed that Total inorganic nitrogen also follow similar trend with NO_2-N, NH_4-N, and $N0_3$- N in Ohaji Egbema soil. Total Inorganic nitrogen correlated positively and significantly with available phosphorous (0.55*) and Silt clay ratio (0.79**). Ammonium nitrogen correlated negatively but not significantly with silt (-0.02), bulk density (-0.36), exchangeable aluminum (-0.17), pH(-0.36) and total exchangeable acidity (-0.17) while Total N and total Organic N also have similar trend of significant correlation. Total Nitrogen correlated negatively and significantly with clay (-0.64*) and showed positive significant correlation with available Phosphorus (0.57*) and silt clay ratio (0.72**). Significantly positive relationship has been reported between available P and total N in Central highland soil, Ethiopia (Duguma, Hager, and Sieghardt, 2010). Significant correlation between NH_4 -N and silt clay ratio could be due to high NH_4-N fixation (Burke, Yonjer, Parton, Cole, Flach, and Schimmel, 1989).

From the result, Total nitrogen and Total Organic Nitrogen also follow similar trend in Oguta soils.. Total nitrogen correlated negatively but not significantly with base saturation (r=-0.25), also correlated negatively and significantly with pH (r=-0.56*) and positively with total exchangeable acidity (r = 0.57*) in Oguta Soil. Total Inorganic nitrogen and No_2-N, NH_4-N, and $N0_3$- N also correlated negatively but not significantly with base saturation (r=-0.17) and silt clay ratio (r=-0.03), total Inorganic nitrogen correlated negatively and significantly with pH

(r=-0.59*). It correlated positively with ECEC (r=0.53*). Ohaji and Emeabiam showed some significance in the soil properties they correlated with.

TABLE 4.5. RelationshipsBetween N Forms and Selected Soil Properties of DifferentLocationsStudied.

Soil Property	TN	TON	NH_4 N	NO_3 - N	NO_2 N	TIN
			EMEABIAM			
Clay	-0.76**	-0.71**	-0.70**	-0.73**	-0.62*	-0.71**
OC	0.95**	0.95**	0.58*	0.74**	0.59*	0.64*
Sand	0.54*	0.51*	0.48	0.50*	0.40	0.48
AP	0.69*	0.74**	0.15	0.36	0.28	0.23
BS	0.48	0.53	0.03	0.21	0.15	0.10
Bulk D.	-0.32	-0.28	-0.46	-0.36	-0.27	-0.41
ECEC	0.24	0.13	0.74**	0.60*	0.58*	0.69*
TEA	0.24	0.13	0.74**	0.60*	0.58*	0.69*
			EGBEMA			
Clay	-0.64*	-0.65*	-0.48	-	-0.40	-0.46
Sand	0.39	0.41	0.24	-	0.18	0.22
Silt	-0.13	-0.15	-0.02	-	0.01	0.00
Bulk D	-0.23	-0.20	-0.36	-	-0.33	-0.35
AP	0.57*	0.57*	0.53*	-	0.57*	0.55*
BS	0.34	0.35	0.23	-	0.12	0.20
EAL	-0.18	-0.17	-0.17	-	-0.15	-0.17
ECEC	0.01	-0.02	0.14	-	0.05	0.11
pH	-0.37	-0.36	-0.36	-	-0.32	-0.36
Silt Clay ratio	0.72**	0.68*	0.80**	-	0.67*	0.79**
TEA	-0.24	-0.24	-0.17	-	-0.15	-0.17
TEB	0.17	0.12	0.30	-	0.17	0.26
			OGUTA			
OC	0.37	0.36	0.36	0.45	0.36	0.41
Sand	0.09	0.08	0.13	0.33	0.46	0.26
AP	0.44	0.44	0.39	0.39	0.43	0.42
BS	-0.25	-0.25	-0.18	-0.17	-0.09	-0.17
ECEC	0.44	0.43	0.53*	0.52*	0.36	0.53*
pH	-0.56*	-0.55	-0.56*	-0.61*	-0.38	-0.59*
Silt Clay ratio	0.17	0.19	0.01	-0.05	-0.08	-0.03
TEA	0.57*	0.57*	0.53*	0.50*	0.37	0.53*
TEB	0.39	0.38	0.48	0.48	0.33	0.49

*and ** = Significant at 0.05,and 0.01probability level respectively, TN= Total Nitrogen, TON = Total Nitrogen, TIN = Total Inorganic Nitrogen,NH_4 N = ammonium N, NO_3 N = Nitrate N, NO_2 N = Nitrite Nitrogen, OC = Organic Carbon, AP = Available Phosphorous, TEA = Total Exchangeable Acidity, ECEC = Effective Cation Exchange Capacity, BS = Base Saturation, TEB = Total Exchangeable Bases.

4.6 Elemental Ratios forFertility Status of Studied Locations

Elemental ratios for fertility status of studied areas are shown in Table 4.6 a, 4.6b and 4.6c.

Fertility status has been measured using different methods. Common ones among them is the use of elemental ratio (Landon, 1991), which is an important parameter used in determining soil fertility.Ca:Mg ratio is usually in the range between3:1 to 7:1. Ca: Mg values lower than 3:1 indicate unfertile soils (Landon, 1991) and may result to deficiency of calcium (Udo *et al* 2009). High Ca: Mg value indicates high fertility.

The results of Ca/Mgratios varied in all the locations studied. The mean values of Emeabiam soils ranged from 2.08- 2.23 while, that of Ohaji Egbema soils ranged from 1.61- 2.12, and Oguta soils ranged from1.28- 2.68. The mean values were low and below the critical limit of 3:1 in all the locations studied.The low values obtained in the studied areas indicate calcium and phosphorous availability. According to Landon (1991), the floodplain soils are of low fertility status. The research findings are in agreement with (Mbah, 2006).

K: Mg ratio of 0.2 -0.3 is ideal (Udo *et al* 2009). K : Mg ratio can be indicative of how available the potassium and magnesium are in the soil. K: Mg ratio greater than 2:1 may inhibit the uptake of magnesium and may be an indicator of soil infertility. K/Mg ratio of soils of studied locations had mean values of 0.02 in all the peons of Emeabiam soils. The mean K: Mg ratio ranged from 1.59 to 2.33, and 0.40-2.66 for Ohaji Egbema and Oguta. Emeabiam had low values in all the pedons, while Ohaji Egbema and Oguta soils were moderate.

Table 4.6a Calcium Magnesium Ratio and Potassium Magnesium Ratio of Emeabiam Location

Horizon	Depth cm	Ca : Mg	K : Mg
		EWS 1	
Ap	0-12	1.64	0.02
AB	12-31	2.20	0.02
BA	31-66	2.63	0.03
Bt1	66-135	2.83	0.03
Bt2	135-200	3.24	0.04
Mean		**2.23**	**0.02**
CV		0.47	0.00
		EWS 2	
OA	0-8	1.93	0.02
A	8-24	2.2	0.03
AB	24-32	2.64	0.03
Mean		**2.17**	**0.02**
CV		0.63	0.75
		EWS 3	
OA	0-6	1.63	0.02
A	6-18	1.74	0.02
AB	18-46	2.70	0.03
BA	46-98	3.26	0.76
Mean		**2.08**	**0.02**
CV		0.29	0.38

EWS= Emeabiam Water Side.

Table 4.6b Calcium Magnesium Ratio and Potassium Magnesium Ratio of Ohaji Egbema Location

Horizon	Depth cm	Ca : Mg	K : Mg
		Egbe 1	
Ap	0-13	1.53	1.47
A	13-34	1.84	1.93
AB	34-60	2.9	1.14
Bt1	60-85	2.86	1.76
Bt2	85-200	1.49	1.99
Mean		**2.06**	**1.59**
CV		1.04	0.76
		Egbe 2	
Ap	0-9	1.42	3.29
A	9-28	1.57	3.07
BA	28-50	2.63	1.2
Bt1	50-90	3.13	1.88
Bt2	90-200	0.63	1.69
Mean		**1.61**	**2.33**
CV		**0.74**	**1.68**
		Egbe 3	
Ap	0-9	2.44	4.33
A	9-26	1.50	1.31
BA	26-46	2.60	1.39
Bt1	46-67	1.50	2.37
Bt2	67-150	2.5	1.8
Mean		**2.12**	**2.16**
CV		2.36	3.14

Egbe = OhajiEgbema

Table 4.6c Calcium Magnesium Ratio and Potassium Magnesium Ratio of Oguta Location

Horizon	Depth	Ca: mg	K: mg
		OGU1	
A	0-10	1.95	4.75
BA	10-47	3.2	1.8
Bt1	47-82	2.36	0.42
Bt2	82-136	3.00	4.72
Bt3	136-200	4.00	0.55
Mean		**2.17**	**2.22**
CV		1.47	2.62
		OGU2	
A	0-12	1.13	0.33
BA	12-53	2.56	0.29
Bt1	53-75	2.91	1.02
Bt2	75-112	2.8	0.2
Bt3	112-200	1.85	0.32
Mean		**2.97**	**0.64**
CV		0.62	2.38
		OGU 3	
A	0-10	3.2	2.68
BA	10-36	0.79	0.07
Bt1	36-78	1.86	0.16
Bt2	78-126	0.8	0.53
Bt3	126-200	3.00	0.53
Mean		**1.28**	**0.45**
CV		0.27	1.29

OGU = Oguta, CV = Coefficient of variation

CHAPTER FIVE

5.0 Summary, Conclusion and Recommendations

5.1 Summary and Conclusion:

Little informationis currently available to farmers and extension workers with regards to soil fertility and nutrient management in floodplain soils of Emeabiam, Ohajiegbema and oguta. Hence the need for this study. Nitrogen forms and fertility status of some selected floodplain soils in Imo State South East Nigeria was conducted. The main objective was to determine the nitrogen forms and fertility status of some selected floodplain soils of Imo State. Three profile pits were dug in each location. A total of forty two (42) samples were collected. The profile pits dug were described using FAO guidelines. Routine analysis was carried out in samples collected. Morphological features in the soils showed that the study areas are low lands. The grey colouration of some soils of Emeabiam soils was attributed to poor aeration due to water logging. The dominant hues were (5YR and 2YR). Emeabiam soils were granular in structure at the surface and angular blocky at the sub surface. Pedon I in Emeabiam soils was well drained while pedon 2 and 3 were poorly drained.Ohaji Egbema was friable at the surface and firm at the sub surface. The brown colour found in Ohaji Egbema is an indication of good aeration and organic matter content. The dominant hues were (5Yand 2.5Y).Ohaji Egbema soils were granular at the surface and sub angular blocky at the subsurface. All the pedons of Ohaji were well drained.The yellowish colour of Oguta soils can be as a result of the presence of ironfound in the soil. The dominant hue was (10YR) Oguta soils were well drained.Oguta soils had granular structure at the surface and sub angular blocky at the sub surface.

The physical propertiesof the soils revealed the dominance of sand fraction over the other fractions with mean values of 900.7g/kg, 850.9g/kg and 950.6 g/kg for Emeabiam, Ohaji Egbema and Oguta respectively.The soils varied from coarse to medium textures (Sand to Loamy sand).The bulk density for the three locations has no limitation tocrop rooting. Mean bulk density of 1.68g/cm^{-3}, 1.25 g/cm^{-3}, and 1.53g/cm^{-3}for Emeabiam, Ohaji Egbema and Oguta respectively. Silt clay ratio of all the soils studied was above 0.15 which is an indicative of young soils.

Chemically the pH of the soils was slightly to moderately acidic.Mean pH value of 6.32, 6.22 and 6.32 for Emeabiam, Ohaji Egbema and Oguta respectively. The soil organic matter, organic carbon, total nitrogen and ECEC of the soils were all low. The Ca : Mg ratio was rated low and below critical limit of 3:1in all the locations. K : Mg ratio was rated low in all the pedons of Emeabiam and moderate in Ohaji Egbema and Oguta. All the nitrogen forms of the studied location were rated high except Oguta soils that had moderate values. Ensuring adequate nitrogen forms under these soils will encourage ecosystem conservation. Ohaji Egbema floodplain soils can be exploited for crop production with good management practices. Ohaji Egbema can be exploited for cultivation of rice, oilpalm, coconut, plantain, pineapple with judicious application of lime and nitrogen and potassium fertilizer. Ohaji Egbema contains high total nitrogen, moderate organic carbon, high base saturation and moderate calcium. The results of the study revealed that the selected floodplain soils of Imo State have low fertility potential for crop productivity.

5.2 RECOMMENDATIONS

Floodplain Soils offers great potential for all season crop production and aquaculture. Based on the findings of this study, the following recommendations are made for sustainable land use.

All the soils in the studied locations were made up of sand, which makes them susceptible to erosion due to loose and poor structure. Planting of cover crops will help to prevent erosion.

All the soils were slightly acidic. Liming in all the locations is important to enhance productivity. Organic carbonand organic matter of the studied areas were low. Use of organic fertilizer to improve the nutrient status of these soils is very important. Floodplain users should allow plant residues to be decomposed on the farm instead of burning them. Incorporation of organic matter, plant residue increases the organic matter content of the soil.

The nitrogen forms were all high in the three locations. Farmers should be aware of some management practices such as continuous application of fertilizer, proper and timely use of recommended fertilizer.

Considering the fact that most of the fertility indices studied reveled low fertility status of these soils, it is recommended that practices that will encourage loss of plant nutrient be avoidedand effort should be made to supplement with organic sources of nutrients. However there is need to indulge in agro environmental practices such as aquaculture, incorporation of organic matter in order to improve the soil.

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APPENDIX 1

Emeabia location

APPENDIX 2

Ohaji-Egbema

APPENDIX 3

Oguta

APPENDIX IV

RESIDUAL SOIL NITRATE NITROGEN FOR EVALUATING N MANAGEMENT

NO_3 – N (mg/kg)	
Low	< 10
Medium	10 - 20
High	20 -30
Excess	> 30

Marx et al (1999). Soil Test Interpretation Guide.

AMMONIUM NITROGEN

2-10 mg/kg are ideal