CHARACTERISTICS AND EFFECTS OF PLUVIAL FLOODING ON SOIL QUALITY UNDER OIL PALM PLANTATION (ELAEIS GUINEESIS), OVIA NORTH EAST, EDO STATE.

BY

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CERTIFICATION

We the undersigned certify that this project was carried out by **ASHIUMAN ODION TRACEY** with matriculation number **SSC1708083** in partial fulfillment of the requirements for the award of Bachelor of Science (B.Sc.) Degree in the Department of Geography and Regional Planning of the University of Benin. Benin City, Nigeria.

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DEDICATION

I dedicate this work to God Almighty for his grace and his mercies, for keeping me alive and for giving me the strength and wisdom to complete this research work.

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ABSTRACT

The study focused on the characteristics and effects of pluvial flooding on soil quality under oil palm plantation in Ovia North East, Edo State in order to avert soil degradation, loss of nutrients and fertility. Soil samples were collected from two sites within the same area which was then labeled as experiment A (Flooded Soils) and experiment B (Non-flooded soils/control) and at depths of 0 – 15 , 15 – 30 and 30 – 45 cm respectively. The soil samples collected were analyzed using standard laboratory procedures. The treatments were non-replicated and the data was analyzed using factorial arrangement in randomized complete block (RCB) design. The result showed that sand and clay particle distribution had the highest value in the non-flooded soils than the flooded soils, silt was higher in the flooded soil. It was only Bulk density (BD) that indicated significant difference (P>0.05).water holding capacity (WHC) and Hydraulic conductivity (K-Sat) value was higher in the flooded soils, there was no significant difference (P>0.05). Porosity value was higher in the non-flooded soils, there was significant difference (P>0.05. The pH and Organic carbon (O.C) value of the flooded soils was higher than the non-flooded soils. Total Nitrogen (T.N) was higher in the non-flooded soils; Its LSD was not significant at 0.05 level of probability. Available phosphorus, Calcium (Ca), Magnesium (Mg) and Sodium (Na) were higher in the flooded soil except Potassium; LSD was not significant at 0.05 level of probability. The LSD of exchangeable acidity (E.A), Effective Cation Exchange Capacity (ECEC) and base percentage was not significant at 0.05 level of probability. Fe, Mn and Zn were higher in the flooded soil, but significant difference (P>0.05) except Zn which is not significant at 0.05 level of probability. It was only Cu was high in the non-flooded soil and LSD indicates no significant difference at P>0.05. From the mean values gotten for SEF and SFI, it was discovered that flooded and non-flooded soil are both fertile and are of good quality. It can be concluded that moderate flooding actually helps to improve the quality of the soil.

CHAPTER ONE

INTRODUCTION

1.0 Background of the Study

A significant constituent of virtually all terrestrial ecosystems is soil but it is repeatedly taken for granted. It can be considered as the ecosystem foundation since soil output determines what an ecological unit will look like in terms of flora and fauna life that it can sustain (Schoonover and Crim, 2015). Soil definition is comparative to the function it provides to the person(s) defining it. From a morphological position, the Natural Resource Conservation Service (NRCS) defines soil as a natural body comprised of solids (minerals and organic matter), liquid, and gases that occurs on the land surface, occupies space, and is characterized by one or both of the following: horizons, or layers, that is distinguishable from the original material as a result of additions, losses, transfers, and transformations of energy and matter or the capacity to sustain rooted plants in a natural environment (Soil Survey Staff 2014a). The Soil Science Society of America (SSSA, 2008) defines soil in terms of its inherent and ecological aspects as the unconsolidated mineral or organic substance on the surface of the Earth that has been subjected to and illustrates effects of natural and environmental factors of: climate (including water and temperature effects), and macro- and microorganisms, conditioned by relief, acting on parent material over a period of time.

As a result of the significance of soils for agriculture and forestry, the environmental processes of degradation and erosion are very vital to the society. Methods of soil conservation and of evaluation of erosion threats have been developed and employed. Therefore, soil may be defined as an unconsolidated mineral matter inhabiting the earth's surface that has been subjected to the influence of the genetic and environmental factors, all acting together over periods of time that differs from the preliminary materials from which it is obtained in many physical, chemical and biological characteristics (Ojo – Ajere, Ogunwale and Oluwatosin, 2011).

Soil quality is "the ability of a soil to function. In particular, soil quality has been defined by a committee for the Soil Science Society of America (Sojka and Upchurch, 1999) as the aptitude of an explicit type of soil to function, within natural or managed ecosystem boundaries, to maintain plant and animal yield, sustain or boost water and air quality, and sustain human wellbeing and habitation. Soil quality can be regarded as the ability of a soil to fulfill its functions in the ecosystem, which are determined by the incorporated procedures of varied soil characteristics. With regards to agriculture, soil quality would be the soil's vigor to sustain crop development without becoming degraded or otherwise damaging the environments.

Warkentin (1995) recommended that soil quality is basically linked to the amount of crops produced. In contrast, other workers have laid emphasis on the import of indicating how soil quality influences feed and food quality or how soil quality affects the locale offered for a broad assortment of biota (De La Rosa and Sobral, 2008). Various additional facets related with the living and dynamic nature of soil will be met if the concept of soil quality is considered in relation to various land uses: forest and rangeland ecosystems, urban and industrial land and recreational uses. On account of the diversity of potential land uses, the concept of soil quality should be viewed as relative rather than an absolute term. Therefore, each soil has a natural capacity to perform a specific function. According to the Soil Quality Institute (USDA, 2006), the soil-quality concept is related to the concepts of sustainability of soil use focus and management, although in some cases it has been principally on polluted land. To do that, the concept of soil quality must include soil productivity, soil fertility, soil degradation, and environmental quality. In this sense, the major activity is dedicated to the evaluation of sustainable soil management systems together with the development of related soil-quality assessments (Doran and Jones, 1996).

One of the factors that affect soil quality is flooding especially pluvial flooding. Pluvial (Surface water) flooding occurs when the soil is over-saturated and/or drainage systems are flooded and the surplus water cannot be absorbed or drained away (Fleming, 2020). Pluvial Flooding can also be caused by prolonged rain or quick, heavy rainfall that cannot be absorbed fast enough. Floods are natural and recurrent phenomena that play a vital ecological role. Flood are linked with several extreme natural events that happen on a geographical area known as a drainage basin, which is also referred to as a river basin, a catchment area or a watershed (Andjelkovic, 2001). Drainage basins can be rural (natural)or urban, the former commonly being much larger than the latter. Therefore, flooding can be rural and urban.

Flooding is debatably the weather-related risk that is most prevalent around the world. It can take place practically anywhere. A flood is defined as water overflowing onto land that typically is dry (Ojeh and Ugboma). Flooding is often considered as a consequence of excessive rainfall, but floods can occur in a number of ways that are not directly connected to continuing weather events. Thus, an absolute account of flooding must comprise processes that may have little or nothing to do with meteorological events. It is apparent that in some definitive sense; the water that is involved in flooding must have fallen as precipitation at some time, conceivably long ago. Although pluvial floods may be unsurprising in the sense that they are normally anticipated to happen at definite times of the year, they never take place on a strict schedule. The length of pluvial floods depends to a great extent on the weather - either very current weather, or precipitation over the previous few months.

The pluvial flooding could be in rural area and especially noticed in permanent crop area such as rubber, cacao and oil palm. The oil palm (*Elaeis guineensis*) is a member of the family Palmae. *Elaeis guineensis* is a species of palm regularly just called oil palm but sometimes referred to as African oil palm or macaw-fat (GRIN, ARS and USDA 2017). It is the prime source of palm oil. It is native to west and southwest Africa, particularly the area between Angola and the Gambia; the species name, guineensis, refers to the name for the area, Guinea, and not the present country now bearing that name. The species is also now naturalised in several such as Madagascar, Sri Lanka, Malaysia, Indonesia, Central America, Cambodia, the West Indies, and several islands in the Indian and Pacific Oceans. The closely related American oil palm *Elaeis oleifera* and a more distantly related palm, *Attalea maripa,* are also used to produce palm oil.

Elaeis guineensis is monocotyledonous. Full-grown palms are single-stemmed and develop to 20 meters. The leaves are pinnate and reach 3–5 meters. An immature palm produces about 30 leaves a year. Established palms over 10 years may produce about 20 leaves a year. The flowers are produced in dense clusters; each individual flower is small, with three sepals and three petals. The palm fruit takes 5–6 months to develop from pollination to maturity. It is reddish and grows in large bunches. Each fruit is made up of an oily, fleshy outer layer (the pericarp), with a single seed (the palm kernel), also rich in oil.

According to Opeke (1992), oil palm grows freely in West Africa chiefly in the southern latitudes between latitudes 10° N and 10° S. Oil Palm is a profitable tree that has a great deal of significance to the economy of Nigeria and the oil palm farmer. Buchanan and Pugh (1995) championed some of the financial significance and import of oil palm to Nigerian farmers when they distinguished that its leaf ribs are employed in building, the leaves in thatching and the fiber in rope making.

Nigeria Institute for Oil Palm Research (NIFOR), Benin City, is primarily concerned with the advancement of novel technologies such as the improvement of hybrids, new farming techniques, better processing techniques and other innovations to guarantee that oil palm production by oil palm cultivators is enhanced and improved upon.

1.1 Statement of the Research Problem

One of the most common of all environmental vulnerabilities is flooding and on a regular basis claims over 20,000 lives per year and negatively affects approximately 75 million people universally (Smith, 1996). Across the earth, floods have created remarkable danger to people's lives and properties. Floods cause about one third of all deaths, one third of all injuries and one third of all damage from natural disasters. (Smith, 1996).

The pattern is analogous in Nigeria with the rest of the world. Flooding in numerous parts of Nigeria have driven millions of people from their abodes, ruined businesses, contaminated water reserves and augmented the menace of diseases as opined by Edward-Adebiyi (1997). Soil nutrient dynamics in pluvial floodplain ecosystems are exceedingly multifarious as a consequence of flood pulses and changing redoximorphic state (Dezzeo, Herrera, Escalanta and Chacon*,* 2000). For the duration of floods, soil nutrients disperse in floodwaters and are transferred from pluvial floodplain surfaces into contiguous rivers, and soil nutrients may also be conveyed from the river into pluvial floodplains through lateral flow (Gallardo, 2003). Pluvial flooding can lead to both increases and decreases in soil nutrient content.

Floods of high degree in humid regions have resulted in grave penalty caused by intense downpours, storms, snow melt and dam failures (Jeb and Aggarwal, 2008). Pluvial flooding results in scarcity of food crops as a result of loss of entire produce and the obliteration of soil quality. When a soil gets flooded (anaerobic conditions), microorganisms use the accessible soil oxygen to stay alive. Free oxygen in the soil is typically exhausted within a couple of days after flooding. The longer the soil is flooded, the lower the soil oxygen levels become more reduced (Walls, Wardop and Brooks, 2005). Oxygen insufficiency is probably the most essential environmental factor that set offs growth inhibition and damage in flooded plants as reported by Visser, Voesenek, Vartapetian and Jackson, (2003).

Notwithstanding the substantial consequences of flooding on the surroundings flood plays an imperative purpose in upholding vital eco-system function and biodiversity in many natural systems. Flood deposits organic materials, minerals and essential nutrients from rivers and oceans into land which makes the soil richer, fertile and more productive. Nevertheless, these environmental benefits come at a high value when extreme flooding occurs, since natural systems can no longer be durable to the effects of great and too much floods (Visser *et al*, 2003). Mounting request for land as a consequence of population increase and food shortage has made farmers to farm in marginal lands such as lands prone to erosion and flooding as observed by Quansah and Sanchez (1997). Flood adds positively to soil characteristics through the provision of nutrients that maybe deficient in the soil as opined by Stephen (1993) and O'Connor (2004). Soaking of the floodplains and fields by floods discharges immediate nutrients that were remaining from the preceding flood and those that result from the swift putrefaction of organic matter that has amassed for the period of the flood. Njoku and Okoro (2011, 2015) reported that soil characteristics such as total porosity, moisture content, pH, and organic carbon were higher in a soil subsequent to flooding than previous to flooding. Heavily vegetated lands are less probable to experience pluvial flooding. Plants retard water as it runs over the land, giving it time to penetrate the ground. Even if the ground is excessively sodden to absorb more water, plants still slow the water’s course and amplify the time between rainfall and the water’s entrance in a stream; this could keep all the water falling over a section to hit the stream straight away. Everglades operate like a bulwark between land and high water levels and perform a vital role in diminishing the impacts of floods (Desonie, 2014). Flooding is frequently more severe in areas that have been freshly saturated.

Researchers have studied how flooding has affected the performance and quality of both the soil and the crops such as disturbances caused by floods in three physical characteristics of a vertisol in the East region of Cuba, cultivated with sugarcane (saccharum spp.) (Rodrigues, Ulloa, Pérez, Rodríguez and Guevara 2016) and Legacy effects of extreme flood events on soil quality and ecosystem functioning." (Chadwick, Jones, Kingham, Rodriguez, Cross and Taft, 2015).

There is therefore scarceness of information on the effects of pluvial flooding on soil quality especially under Oil Palm Plantation. Besides, this work is carried out with the intent of contributing to knowledge as well as filling the knowledge gaps.

This research centers on the assessment of the effects of pluvial flooding on soil quality under oil palm (*Elaeis guineesis*) plantation in Ovia North East, Edo State based on some selected areas where flooding was great and areas where there was no flood. It was on this basis the following research questions were put forth to provide guidelines to this study;

(a) Are there any differences in the morphological, physico-chemical and biological characteristics of soils between the flooded soils and the non- flooded soils?

(b) Are the effects of flooding on soil quality under oil palm (*Elaeis guineesis*) plantation beneficial or detrimental?

All these issues ought to be answered in details in the course of this study.

1.2 Aim and Objectives

The aim of this research is to examine the characteristics and effects of pluvial flooding on soil quality under oil Palm (*Elaeis guineesis*) plantation in Ovia North East, Edo State. In order to realize this goal, the specific objectives are to:

(i) examine if there are differences in the morphological, physico-chemical and biological characteristics of soil between the area most flooded and the areas which are less flooded,

(ii) determine whether pluvial flooding has any impact on the agricultural land,

(iii) determine the effects of pluvial flooding on quality of soils under oil palm (*Elaeis guineesis*) plantation, and

(iv) provide Stakeholders such as plantation owners, farmers, NIFOR with vitalsystematic information to be able to make conversantjudgments.

1.3 Research Hypotheses

(a) There is no significant difference in the morphological and physico-chemical and biological characteristics of the flooded soils and the non-flooded soils.

(b) There is no significant difference between the quality of the flooded soils and the non-flooded soils.

1.4 Scope of the Study

What this research work entails is to examine the disparities in the morphological and physico-chemical characteristics of soil as a result of pluvial flooding under oil palm plantation in Ovia North East, Edo State. The location which was picked for this study was the areas where the impact of flooding was seen to be great as well as areas where flooding was less within the oil palm plantation. The physico-chemical soil characteristics which was examined includes the following: bulk density, hydraulic conductivity, clay, sand, silt, soil colour, soil texture, soil pH, soil organic matter, soil structure, soil consistency, soil mottles, soil, micronutrients and macronutrients, effective cation exchangeable capacity and exchangeable acidity.

1.5 Significance of the Study

Even though flooding has several great harmful impacts on individuals, it is also a component of the natural processes influencing the world. Floodplains beside rivers and streams are amongst the mainly lush areas known. The majority of the purported cradles of civilization' are inside floodplains for this very rationale. Consequently, human beings have been influenced by flooding both optimistically and pessimistically since before historical times, whenever they find themselves in the course of these natural events (Doswell III, 2003).

Flood plays an essential role in maintaining key ecosystem functions and biodiversity in many natural system. Flood leaves organic materials and essential nutrients from rivers, streams, and oceans into land which makes the soil fertile, richer and more productive. The destructive impact of flooding and its accompanying harmful outcomes on agricultural soils, therefore causing weakening in soil quality accentuates and dictates the need for this research study. This study will consequently provide stakeholders e.g. NIFOR, oil palm plantation owners, farmers, researchers and even those that might be interested in information with regard to flood vulnerability. This study will also act as a guide for future studies of pluvial flooding that may take place in the oil palm plantation.

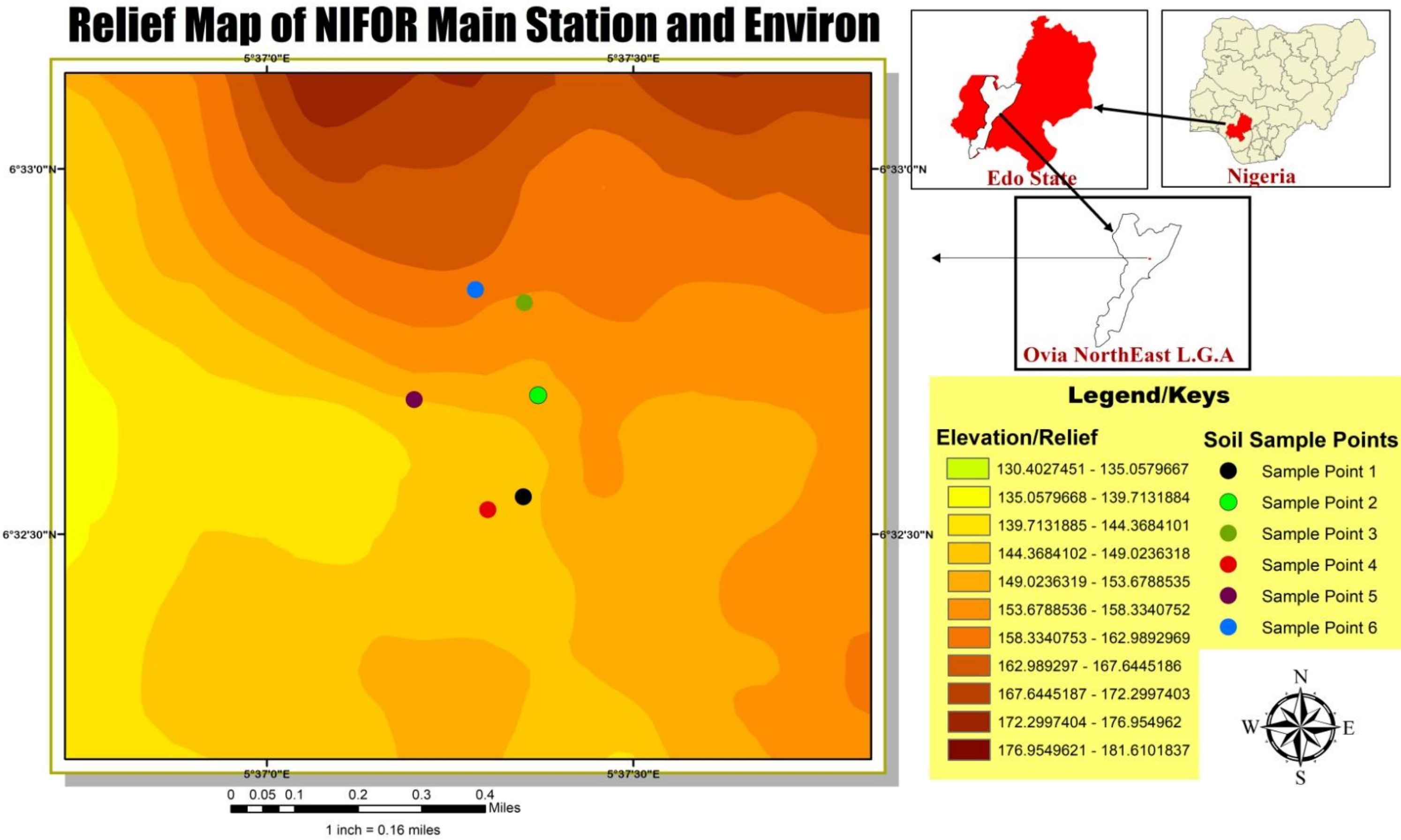

Fig 1.1: Relief map of NIFOR and Environ

1.6 The Study Area

The area of study is in Ovia North East, Edo State (Figure 1.1) Ovia North East is a local government area of Edo State, Nigeria. It's headquarter is in Okada. It has an overall area of 2,301km^2 and an estimated population of 227,049 in 2020. Ovia North East is made up of several towns and villages such as Okada, Uhen, Kokhuo, Ofum-Wengbe, Uhiere, Isiuwa, Adolor, Oluku, Iguoshodin, Utoka, Oghede, Oduna. The Specific study area is NIFOR in Isiuwa.

NIFOR is situated Northwest of Ugbokun junction with latitude of 6.6062° (6°36'22.4") and Longitude of 5.4201° (5°25'12.3") it has an altitude of 150 meter. Isiuwa has a postcode which is 302115. NIFOR is a research institute with the mandate of researching into the genetic improvement, production and processing of oil palm, raffia, date palm, coconut and ornamental palms.

1.7 Justification of the Areaof Study for this Research

The area of study is suitable for this research work based on the following reasons:

(a) The area of study has both flooded soils and non-flooded soils (control).

(b)The shape of the area which is saucer-shaped, slope angle, length, channel density and elevation all makes it a reason to study flooding.

(c) The type of land use which is agricultural makes it convenient for this research work.

(d) The Institute has a Library for acquisition of knowledge.

(e) The vegetation type which is found in the area of study.

CHAPTER TWO

CONCEPTUAL FRAMEWORK AND REVIEW OF THE LITERATURE

2.0. Conceptual Framework

The notion of soil quality has been an item of debate amongst soil scientists as a result of it being subjective as well as management and climate dependent. The idea has not been meticulously tested by the scientific community (Karlen., Mausbach, Doran, Cline, Harris, and Schuman, 1997), but it has been institutionalized by some scientific association and government organizations regardless of the dissonance surrounding it. In contrast, concepts of air and water quality are well received and Karlen *et al*., (1997) further opined that they are founded on customary untainted circumstances against which all qualities can be calculated. It might appear realistic to take account of soil quality as a fundamental natural resource. There seem to be no ideal soil state existing that can be measured for all possible uses.

In the United States, soil quality includes soil fertility, potential productivity, resource sustainability, and environmental quality. Till date most appraisals have been associated primarily to microbial diversity and/or crop yield. In Canada and Europe, contaminant levels and their effects are the primary factors determining soil quality (Doran, Sarrantino and Liebig, 1996). Majority of farmers and agricultural scientists who have accepted the concept of soil quality have related it chiefly with crop yield. Some enlarge this to comprise explicit Indicators such as soil physical and chemical conditions, organic matter content, and/or microbial respiration. Critics of the concept note that, regardless of the greatest of intentions, such exemplars fall short to resolve the disagreement that some soil characteristics connected positively with output have harmful impacts on environmental quality.

Karlen *et al.,* (1997) reported that The Soil Science Society of America Ad Hoc Committee on Soil Quality recommended that soil quality is the competence of a particular type of soil to function, within natural or managed ecosystem boundaries, to preserve plant and animal productivity, sustain or augment water and air quality, and maintain human wellbeing and habitation. This explanation necessitates that the following soil functions be appraised simultaneously to depict soil quality: (1) supporting biological activity, multiplicity, and productivity; (2) regulating and dividing water and solute flow; (3) buffering, filtering, ,immobilizing, detoxifying and degrading organic and inorganic materials, including industrial and municipal by-products and atmospheric deposition; (4) cycling and storing nutrients and other elements within the Earth's biosphere; and (5) providing support of socioeconomic structures and protection for archeological treasures connected with human habitation. Quantification of the Ad Hoc Committee's general definition is complex since no single conserving or degrading process or property determines soil quality.

Soil has both dynamic and static characteristics that vary spatially. In addition, soils carry out diverse functions, often concurrently, for which quantitative liaisons among calculated values and expected responses are deficient (Dela Rosa and Sobral, 2008).

Singer and Ewing (2000) have evaluated other descriptions of soil quality. The existence of numerous definitions implies that the soil quality concept is budding. Every soil quality definitions have some similarities. High-quality soils are productive and biologically active; they sustain plant productivity and human and animal health; and they serve in dissimilar capacities in unmanaged ecosystems. In particular, high-quality soils are those that sufficiently control water, nutrient, and energy flow through the environment, while providing barriers against detrimental environmental changes. An incorporated visualization of soil quality has been suggested in definitions, but its characterization and indexing have centered on limited individual facets of the definition without attempting to fit in the contradictory functions.

2.1. SOIL CHARACTERISTICS

Soils are composed of organic and inorganic matters. There are three fundamental soil types: sand, silt, and clay. Sand consists of tiny rock fragments and is the coarsest in terms of texture. Clay becomes greasy or sticky when wet, and firm when dry. Silt is between sand and clay in texture and it is a micro-sand (Ugwa, Orimoloye, Kamalu and Obazuaye, 2017). Loam as an example is an amalgamation of sand, silt, and clay, and has a high percentage of organic matter. It is a very good soil for most plants. (Soil Survey Reports, 1999).Approximately all soils found in nature include some amount of two or more of the three soil types along with some organic matter. Therefore soils vary in the proportions of clay, silt, sand, and organic matter.

The necessary nutrients are supplied by the putrefying organic material in the soil. Levels of nutrients such as carbon (C), phosphorus (P), potassium (K), and nitrogen (N) in soil is effortlessly tested. Plants also use numerous other nutrients and are influenced by other biological activities operating on the soils. Plant growth is also affected by other abiotic factors such as air and soil temperature, air moisture (humidity) and soil moisture levels.

2.1.1 SOIL PHYSICAL CHARACTERISTICS

Soil Texture

An easy meaning of soil texture is how the soil feels when it is rubbed between the fingers, while the technical definition is the relative proportion of sand, silt and clay in the soil. The basic textural classes, in order of rising quantity of fine particles, are sand, loamy sand, sandy loam, loam, silt loam, silt, sandy clay loam, clay loam, silty clay loam, sandy clay, silty clay, and clay (Soil Survey Reports, 1999).

Soil Structure

Soil structure is the arrangement of soil particles into aggregates, and the pore space around them (Soil Survey Reports, 1999). Aggregates can be natural or made by people (e.g., by tillage in wet soils; these aggregates are called clods). Soil aggregate according to Buol *et al,* (2011) can be described as type, class and size. Aggregate stability is the capacity to resist wetting and drying, wind, and actions such as tillage (USDA, 2013). Aggregate stability is caused by biological factors which include bacterial and root exudates, fungal hyphae, macro-fauna activities and organic matter content. Soils high in sand and silt do not form aggregates well. The type and quantity of clay particles wholly influences how well aggregates form and how they persevere.

Bulk Density

The bulk density of the soil is the mass of a specified amount of oven dried soil divided by the volume, and reveals the sum of pore space in the soil. It is an indicator of soil vigor (National Soil Survey Handbook, 1998). Soil bulk density values range from 0.5 to 3.0 but most values are between 0.8 and 1.8. Anything denser than about 1.8 is root restrictive. There are factors that have an effect on bulk density which comprise types of minerals that make up the soil particles, soil texture, organic matter content, and soil compaction.

Soil Organic Matter (SOM)

Organic matter consists of dead microbes, fungi, plants and animal, as well as animal and microbial waste products in different stages of putrefaction. (Soil Survey Reports, 1999). Sooner and or afterward, every single one of these break down into humus which is comparatively constant in the soil. Organic matter can be in different forms. The amount of organic matter the soil can hold is actually in equilibrium. Organic matter added further than a soil's equilibrium is overflow, and is broken down to carbon dioxide and water (Soil Survey Reports, 1999). There is an utmost quantity of organic matter that any particular soil can hold, and that quantity is inversely proportional to soil temperature and moisture. Wetter and colder soils can hold higher magnitudes of organic matter than drier and warmer soils.

Soil Colour

Soil colour varies with parent material, the length of soil forming processes and the environment itself. Soil colour is explained using Munsell Colour Notation. The notation breaks soil color into hue (the particular colour), value (how light or dark the colour is), and chroma (how the colour is). Drainage and wetness (also called redoximorphic features) also affects soil colour. Greenish, bluish, and gray colours in the soil signify wetness. These colours may occur as the overriding colour (the matrix) or in patches (mottles). These colours will endure even if the area is drained. Vivid colours (reds and yellows), indicate well-drained soils. Nevertheless, colour should not be the lone indicator for determining the soil's suitability for crops. Vivid colors at times still have surplus free water in budding season if the groundwater is running more rapidly and has sufficient oxygen or too cold for any biological activity (Soil Survey Reports, 1999). Dark colours in the soil regularly indicate presence of organic matter. However, they may also indicate wetness as wetter soils can amass more organic matter. Occasionally dark colors may be originated from the parent material if they are formed from dark-colored igneous rock.

Water Holding Capacity (WHC)

Water holding capacity is the greatest quantity of water that the soil can hold that is accessible for plant growth. It is the dissimilarity between the quantity of water in the soil at field capacity and the quantity of water in the soil at wilting point (Brady and Weil, 2002). It is also known as Available Water Capacity (AWC) and as Plant Available Water (PAW) (National Soil Survey Handbook, 1998).Important factors influencing water holding capacity include salts, soil depth, organic matter, compaction and coarse fractions such as stone and gravel.

Soil Porosity

Pores are the gaps between soil particles or aggregates. They are the air and water – filled spaces between particles. Soil pores are vital because they permit air and water to travel through the soil. Without air, roots as well as organisms cannot survive. Kinds of pores include interstitial pores and tubular pores while pores are broken to micro- and macro- sizes. Various significant soil processes take place in soil pores. Soil texture and structure influences soil porosity by determining the size, number and interconnection of pores (Esu, 1999). Coarse-textured soils have many macro-pores because of the loose arrangement of bigger particles with one another while fine textured soils are more tightly arranged and hence have more micro-pores. Because fine textured soils have both macro- and micro-pores, they usually have greater total porosity. Porosity and structure may be modified by management, water and chemical processes. Extended cultivation tends to lower total porosity as a result of a decline in soil organic matter and large peds (Brady and Weil, 2007).

Hydraulic Conductivity

Hydraulic conductivity is a measure of promptness with which a inundated soil transmits water through its body and it is expressed as length per unit time. Hydraulic conductivity is of a substantial import for irrigation, drainage and evaporation studies

(Kadam and Shinde, 2005). It depends upon properties of water/fluid and on the porosity, pore size distribution and continuity of soil pores. Since viscosity and density of water passing through the soil affect the hydraulic conductivity, this soil property varies for different quality of waters. The hydraulic conductivity of soil varies from 0.001 cm/hr in fine clay to over 25.0 cm/hr on coarse sand.

2.1.2. SOIL CHEMICAL CHARACTERISTICS

Soil pH

Soil reactivity is expressed in terms of pH and is a measure of the acidity or alkalinity of the soil. Soil pH is a vital characteristic that can be used to make informatory analysis both qualitative and quantitatively concerning soil characteristics (Thomas, 1996). More specifically, it is a measure of hydrogen ion concentration in an aqueous solution and ranges in soils from 1- 14. pH is defined as the negative logarithm (base 10) of the activity of hydronium ions in a solution. In soils, it is measured in a slurry of soil mixed with water (or a salt solution, such as 0.01 M $CaCl_2$), and usually falls between 3 and 10, with 7 being neutral. Acid soils have a pH below 7 and alkaline soils have a pH above 7. Ultra-acidic soils (pH < 3.5) and very strongly alkaline soils (pH > 9) are rare (Slessarev, Lin, Bingham, Johnson, Dai, Schimel, and Chadwick, 2016; Queensland Department of Environment and Heritage Protection, 2017).

Soils with high acidity (<5.5) tend to have toxic amounts of aluminum and manganese. Soils with high alkalinity (>8.5) tend to disperse the soil. Soil organisms are hampered by high acidity. Soil pH is considered a master variable in soils as it affects many chemical processes. It particularly affects plant nutrient accessibility by controlling the chemical forms of the different nutrients and influencing the chemical reactions they undergo. The optimum pH range for most plants is between 5.5 and 7.5 (Queensland Department of Environment and Heritage Protection, 2017); however, many plants have adapted to flourish at pH values outside this range.

Plant nutrients

There are sixteen nutrients vital for plant maturation and living organisms in the soil. These fall in two diverse categories, macro- and their micro- nutrients. The macronutrients such as Phosphorus (P), Nitrogen (N), and Potassium (K) are the most vital nutrients to plant growth and development whereby a higher quantity of these is needed. The micronutrients on the other hand are needed in little quantities s some of them include Zinc (Zn), Manganese (Mn) Iron (Fe) and Copper (Cu). Almost all plant nutrients are taken up in ionic forms from the soil solution as cations or as anions.

i. Nitrogen

Nitrogen is a major component of several of the most significant plant substances. For instance, nitrogen compounds consist 40% to 50% of the dry matter of protoplasm, and it is a component of amino acids, the building blocks of proteins (Swan, 1971a). It is also an important component of chlorophyll (Roy, Finck, Blair and Tandon, 2006). In diverse agricultural settings, nitrogen is the restrictive nutrient for rapid growth. It is significant to plants for metabolism as it is also an essential substance in amino acids, proteins and enzymes. It plays a vital role in photosynthesis, responsible for rapid growth of foliage and provides green color to the plants. Nitrogen insufficiency most often results in stunted growth, slow growth, and chlorosis. Nitrogen deficient plants will also show a purple appearance on the stems, petioles and underside of leaves from retention of anthocyanin pigments (Norman and Huner, 2008).

ii. Phosphorus

It is important to plants for: development of roots, maintaining good quality of flowering, fruiting and seed production, storing and transporting energy, resistance to disease. Excessive amounts of phosphorus can cause lower reception and deficiency of other elements like Zn, Fe, Cu, Mn and B. On the other hand, according to Black, (1957) phosphorus deficiency can produce symptoms similar to those of nitrogen deficiency, characterized by an intense green coloration or reddening in leaves due to lack of chlorophyll. If the plant is experiencing high phosphorus deficiencies the leaves may become denatured and show signs of death. Occasionally the leaves may appear purple from an accumulation of anthocyanin. Phosphate deficiency differs from nitrogen deficiency in being extremely difficult to diagnose, and crops can be suffering from severe starvation without there being any outward signs that lack of phosphate is the cause (Russell, 1961).

iii. Potassium (K)

Potassium is dissimilar when compared to other major elements, it does not go into the composition of any of the important plant constituents involved in metabolism (Swan, 1971a) but it can occur in all parts of plants in significant quantities. It is of import for enzyme activity including enzymes involved in primary metabolism. It plays a part in turgor regulation, effecting the functioning of the stomata and cell volume growth (Sustr, Soukup and Tylova, 2019). Insufficiency of K in plants contributes to growth reduction, burning or yellowing of the leaf margins and dead spots on older leaves. Abundant quantities are also not as advantageous as they affect the absorption of other nutrients including magnesium, calcium and nitrogen.

iv. Magnesium (Mg)

Magnesium is the powerhouse behind photosynthesis in plants (Cakmak, 2013). Without magnesium, chlorophyll cannot capture sun energy necessary for photosynthesis. In a nutshell, magnesium is needed to give leaves their green color. Magnesium in plants is can be found in the enzymes, in the heart of the chlorophyll molecule. Magnesium is also used by plants for the metabolism of carbohydrates and in the cell membrane stabilization. The role of magnesium is key to plant growth and health. Magnesium deficiency in plants is frequent where soil is not rich in organic matter. Excess rains can cause an insufficiency to happen by leaching magnesium out of sandy or acidic soil. Furthermore, soil comprises of high amounts of potassium, plants may incorporate this in lieu of magnesium, leading to a deficiency. Plants that are lacking magnesium will show distinguishable characteristics. Magnesium deficiency emerges on older leaves first as they become yellow between the veins and around the edges. Brown, purple or red may also emerge on the leaves. Eventually, if left unchecked, the leaf and the plant will die.

v. Calcium (Ca)

Calcium in plants occurs predominantly in the leaves, with reduced concentrations in seeds, fruits, and roots. A notable function is as a component of cell walls. When added with certain acidic compounds of the jelly-like pectins of the middle lamella, calcium forms an insoluble salt. It is also intimately involved in meristems, and is of particular import in root development, with roles in cell division, cell elongation, and the detoxification of hydrogen ions. Other functions attributed to calcium are; the neutralization of organic acids; inhibition of some potassium-activated ions; and a role in nitrogen absorption. A notable feature of calcium-deficient plants is a defective root system (Russell, 1961). Roots are usually affected before above-ground parts (Chapman, 1966). Blossom end rot is also a result of inadequate calcium (University of Zurich, 2011).

Calcium regulates transport of other nutrients into the plant and is also involved in the activation of certain plant enzymes. Calcium deficiency results in stunting. This nutrient is involved in photosynthesis and plant structure (University of Zurich, 2011 and University of Arizona, 2012). It is needed as a balancing cation for anions in the vacuole and as an intracellular messenger in the cytosol (White and Broadley, 2003).

Calcium deficiency is easily managed through proper nutrition. Adding a high quality calcium source to a foliar nutritional program will aid in mitigate deficiencies. As a result of its limited movement in the plant, adding calcium during critical development stages such as fruiting can vastly improve fruit quality, quantity and overall plant health. Calcium can also be added to soil fertility programs and applied in irrigation water to make sure enough levels are spoon fed to the plant.

vi. Sodium (Na)

Sodium is not an essential element for plants but can be used in small quantities, similar to micronutrients, to help in metabolism and synthesis of chlorophyll. In some plants, it can be used as a partial replacement for potassium and assists in the opening and closing of stomates, which helps regulate internal water balance (Bloodnick, 2021). Chloride is needed in small quantities and aids in plant metabolism, photosynthesis, osmosis (movement of water in and out of plant cells) and ionic balance within the cell. Sodium can potentially replace potassium's regulation of stomatal opening and closing (Norman and Huner, 2008).

vii. Copper (Cu)

Copper (Cu) is part of the eight essential plant micronutrients. Copper is needed for various enzymatic functions in plants and for chlorophyll and seed production. Deficiency of copper can lead to increased susceptibility to diseases like ergot, which can cause significant yield loss in small grains.

viii. Iron (Fe)

Iron is vital for photosynthesis and exists as an enzyme cofactor in plants. Iron deficiency can lead to interveinal chlorosis and necrosis. It also aids in the electron transport of plant. Iron is not a structural part of chlorophyll but very much essential for its synthesis. Copper deficiency can be responsible for endorsing an iron deficiency.

ix. Manganese (Mn)

It is significant to plants because it assists in chloroplast production, actively engaging in photosynthetic process, activation of enzymes and influencing germination and crop maturity, Deficiency in Mn may lead to chlorosis.

x. Zinc

It is vital to plants for early growth stages, development of root, seed and fruit, In the process of photosynthesis, balancing plant hormones, activity of auxins. Deficiency of Zinc results in stunted growth, length reduction of internodes, smaller young leaves, and yellowing on the lower leaves.

Effective Cation Exchange Capacity

The effective cation exchange capacity (ECEC) is defined the total quantity of exchangeable cations that a soil can absorb to its surfaces at the actual pH of the soil. Positively charged ions (cations) such as Na^+, K+, Mg^{2+}, Ca^{2+}, Mn^{2+}, Al^3, Fe^{2+}, H^+ are generally adsorbed on negatively charged soil surfaces. At low pH it is mainly the permanent charges of the 2:1 type clays that adsorb exchangeable cations. With increasing soil pH, the positively charged ions are increasingly adsorbed to surfaces with a variable charge such as 1:1-type clays, allophane, soil organic matter and Fe- and Al-oxides (Weil and Brady, 2016).

Base saturation (percentage)

There are acid-forming cations (hydrogen and aluminum) and there are base-forming cations (calcium, magnesium, potassium and sodium). The fraction of the base-forming cations that occupy positions on the soil colloids is called the base saturation percentage. When the soil pH is 7 (neutral), base saturation is 100 percent and there are no hydrogen ions stored on the colloids. Base saturation is nearly in direct proportion to pH and except for its use in calculating the quantity of lime required neutralizing an acid soil, it is of little use (Soil Survey Reports, 1999).

2.1.3 SOIL BIOLOGICAL CHARACTERISTICS

Soil Biota

The soil environment is flourishing with biological life and is one of the most plenteous and various ecosystems on earth (McCauley, Jones and Jacobsen, 2005). Soil biota, including flora (plants), fauna (animals) and microorganisms execute functions that impart to the soil's development, structure and productivity. General characteristics and functions of these groups are presented below:

1. Soil Flora

Plants act on the soil environment by assisting in the structure and porosity, and in supplying SOM through their shoots and root residues. Root channels allow means for water and air movement. Generally, roots act to stabilize soil through aggregation processes and can decrease soil loss.

2. Soil Fauna

Lee (1985) reported that soil fauna work as soil engineers, initiating the breakdown of dead plant and animal material, ingesting and processing large amounts of soil, burrowing biopores for water and air movement, mixing soil layers, and increasing aggregation. Significant soil fauna include earthworms, insects, nematodes, arthropods and rodents. Earthworms are considered one of the most important soil fauna. Through the process of burrowing, they supply channels that increase a soil's porosity, water holding capacity and water infiltration. They also increase further biotic activity by breaking down large amounts of SOM through digestion and supplying nutrient-rich secretions in their casts (Savin,Görres, and. Amador, 1994). In addition, earthworms are able to build soil by moving between 1 to 100 tons of subsoil per acre per year to the surface, possibly aiding offset losses by erosion (Magdoff and van Es, 2010).

3. Soil Microorganisms

Microorganisms (microbes) are invisible to the naked eye. However, their effects on numerous soil characteristics are far reaching. Microorganisms are the most abundant and diverse biotic group in the soil, with an estimated one million to one billion microorganisms per one gram of agricultural top soil (Tugel and Lewandowski, 1999). Microbes help soil structure by gluing the soils through the secretion of organic compounds, mainly sugars. This often results to the formation of granular structure in the A horizon where microbial populations are greatest.

Soil microbes include bacteria, protozoa, algae, fungi and actinomycetes. Bacteria are the smallest and most vast soil microbes. Bacteria are vital in SOM decomposition, nutrient transformations and small clay aggregation. Algae, like plants, photosynthesize and are found near the soil surface. Fungi are those microbes that are extremely important in the disintegration of SOM and large aggregate stability. Many fungi have long hyphae or mycelia (Tugel and Lewandowski, 1999). An essential relationship found in almost all soils and plants, including many crop species, are mycorrhizae. Mycorrhizae are a plant-fungal symbiosis (a relationship between two interacting species) in which fungi infect and live in, or on, a plant root. The fungus relies on the plant for energy, and in return, the fungus and its hyphae can take up nutrients for the plant, and possibly improve plant growing conditions. (Smith and Read, 1997).

2.1.4. LITERATURE REVIEW

In tropical and subtropical regions, intense rainfall during the rainy season occasionally triggers short-term flooding in crop fields. Soil flooding happens over a vast regions throughout the world (Kozlowski, 1984) unfavorably affecting approximately

10% of the global land area (FAO, 2002). Inundation of land for a long period is hazardous even for wetland crops, particularly if the standing water is stagnant. Soil flooding has long been seen as a major abiotic stress and the constraints it imposes on roots have marked effects on plant growth and development (Parent, Capelli, Berger, Crevecoeur and Dat, 2008). Flooding represses aeration of the soil creating an oxygen-free environment in the root zone.

Akamigbo (2001) reported that soils in the flooded area which may be classified as Iintrazonal and Azonal soils developed as a result of factors such as drainage or parent materials. The Wetland and flooded soils in Nigeria, according to Ojanuga, Okunsami and Lekwa (1996) are associated with inland depressions, alluvial plains and coastal plains. The problems generally associated with flooded areas have been reported by Omoti (2001) to include the physical, hydrological and chemical characteristics of the soils as well as efficient drainage and reclamation of the soils. It also includes packages of the soil management for the sustainable utilization of these soils such as conservation reserve program (CRP), terraces, scouting, precision chemical application, crop rotation and irrigation.

Akpoveta *et al.,* (2014) carried out an investigation on post flooding effect on soil quality in Nigeria. The study focused on the post effect of Nigeria's major flooding in 2012 on soil quality parameters in agricultural farmland from two neighbouring states, Okwei at Asaba, Delta state and Fegge at Onitsha, Anambra state respectively so as to provide a quick estimation and evaluation of its effect on the soil for agricultural purposes. The mean pH values for soil samples collected from farmlands in Fegge, Onitsha and Okwei, Asaba were found to be 7.10 and 6.70 accounting for a 14% and 9% decrease respectively, as against that for the control soil from Farmland in Alihame, Agbor which was 7.8. The control soil was weakly alkaline than those of the flood affected farmland areas. There were considerable decreases ranging from 4% to 53% in the values of pH, total organic carbon, total organic matter, total nitrogen, total phosphorus and cation exchange capacity on the flood affected farmlands when compared to the control farmland, except for electrical conductivity where an increase of 54% and 92% at the flood affected farmlands in Asaba and Onitsha was observed when compared to the control. Higher moisture contents were also recorded to about 17% and 45% at the flood affected farmlands in Asaba and Onitsha respectively when compared to the control. Slightly alkaline soils are necessary for improved soil quality as it decreases toxic metal availability with increasing pH. Soil saturated with water causes pH decrease due to organic acid produced from fermentation.

Similarly, Ubuoh *et al.*,(2016) investigated the effects of flooding on soil quality in the Abakaliki Agro-ecological zone of South-Eastern state, Nigeria. The study focused on the effects of flooding on soil quality for proper soil and flood management to prevent soil degradation. All the soil characteristics assessed were significantly different ($p<0.05$) among the study locations. The results further showed that apart from sand, bulk density, gravimetric moisture that were higher in control, parameters such as silt, clay and porosity recorded highest mean values than control. The pH in floodplains recorded mean value of 5.9 being acidic than control with the mean of pH5.38. In addition, Nitrogen, ECEC and Base Saturation (BS) (%) were higher in control than in floodplains. It seems that flood best management practice should be supported in order to retain soil nutrients, reduce soil and water pollutions for ecosystem sustainability.

Soil acidity is part of the major problems for agricultural production in many parts of the world. Incessant flooding on farmlands will inexorably lead to gradual decrease in soil pH, therefore tending the soil towards increased acidity which is a problem for agriculture. The observed pH decrease in the flood affected soils is similar to the findings of Kalshetty, Giraddi, Sheth and Kalashetti (2012) where pH of cultivated soil reduced on flooding from river Krishna in Bagalkot District, Karnataka State, Southern India.

An investigation was carried out on the effects of flooding on the seed bank and soil characteristics in a Conservation area on the Han River Floodplain, South Korea, (Lee,Alday, Josu, Kang-Hyun, Eun Ju and Marrs, (2014). The study revealed that there were important differences in most of the soil physico-chemical characteristics between the pre- and post-flood conditions; soil moisture content, pH and extractable P concentration either staying the same or increasing after the flood but extractable Na concentration decreased. There were other variables showing inconsistent patterns between communities. Multivariate analysis helped interpret the effects creating a clear gradient between sites that were based on particle size. After the flood some communities showed on this gradient changed indicating different-sized sediments by the differing structures found in these plant communities.

Another research was undertaken by Akter, Khan, Hussain and Mazumder (2011) on the physico-chemical characteristics of the seasonally flooded soils on Bangladesh and their management implications. The seasonally flooded soils of Bangladesh are unparalleled in respect of several particular characteristics and contribution toward producing bulk of its staple food, mainly rice. Having fine texture, these soils are comparable to the paddy soils of Southeast Asian floodplains and have high production potential under proper management. These soils receive several mineral nutrients annually with the sediments deposited during the monsoon floods. The characteristics like organic matter content, particle size distribution, CEC, pH and Base Saturation (%) that have important management implications were discussed. The study area covers over a million hectare in the central hydro-ecological region of Bangladesh. The annual flooding characteristics, subsoil horizon, plough-pan, flood coatings, matrix colour and mottles and consistence are the notable morphological features significant to the management of these soils.

The researches carried out were to determine the effect of flooding on soil quality, seed bank, soil characteristics and on physico-chemical properties of soils. Result revealed that, the effects of flooding was the reduction in soil alkanity and the increment in soil acidity while certain variables remained consistent, but other variable changed after flooding.

CHAPTER THREE

RESEARCH METHODOLOGY

3.0. Introduction

In this chapter, the types and sources of data as well as the procedures and methods adopted for data collection, laboratory analyses of the soil sample, data presentation and statistical analysis shall be presented.

3.1 Types and sources of Data

The data which were required for this research include the following:

(a). Soil depths with layer crops.

(b). The physico-chemical characteristics of the soils.

The soil physico-chemical characteristics were obtained from the laboratory analyses of soil samples taken randomly and at depths of 0- 15 cm (upper topsoil), 15 - 30 cm (lower topsoil) and 30 - 45 cm (subsoil) respectively.

3.2. Reconnaissance Survey

Preceding the field work for the research, a reconnaissance field survey was conducted with the purpose of:

i. Getting acquainted with the study area.

ii. Identifying the potential problems and challenges to be encountered.

iii. Reviewing existing environmental information on the study area in published and unpublished literature, and

iv. Planning the field work, getting firsthand knowledge about the appropriate instruments required for the field work.

The instrument required for the fieldwork were cutlass, shovel, Elderman soil auger, polythene bags, measuring tape, camera, white masking tape, notebook and pen, and Global positioning system (GPS) handset receiver.

3.3 Selection of Land Use Type

For the purpose of this research work, the selected land use type is oil palm plantation dominated by tall trees, climbers, epiphytes and thick bushes (Plate 3.1) as the control site. The other location was the area where the impact of flooding was great as a result of the young short oil palm trees interspersed with vegetation (Plate 3.2). To show spatiality, six sampling points from the sites were randomly selected with a length of 200 m at interval. Three sampling points per site were selected the control (non-flooded site) and the flooded site with soil samples collected at depths of 0 - 15 cm (upper topsoil), 15-30 cm (lower topsoil), 30 – 45 cm (subsoil) respectively. The control site serves as the basis for comparing soil characteristics in the flooded and non flooded area. This will further help to show if there are variations and differences in the quality of soils amongst and between the flooded and control sites respectively. The geographical location and elevation of the sampling points were geo-referenced using Garmin Global Positioning System (GPS) handset.

3.4 Field Measurements and Soil Sampling

The total length of flooded area and control was 130 meters and 50 meters wide each. These sampling areas were taken into account due to the nature of flood, labour availability and the similarity of the vegetation and soil type. The soil samples were collected using the soil bulking methodology, using the Elderman soil auger. These soil samples were collected at three depths, 0-15cm, 15-30cm and 30-45cm from the different sampling points respectively. The sampling depths of 0-15cm, 15-30cm and 30-45cm give a reasonable estimate of the availability of soil plant nutrients while soil mineralization occurs mostly in the first 30cm of the soil profile. Orobator (2019) reported that below these depths, profile development in the tropical soils is usually minimized as well as microbial activities. The highest soil depth is 45 cm in which De Oliveira and Valle (1990) also reported that after this depth, there may not be any profile differentiation and much biological activities. According to Buol and Eswaran (1999) and Ugwa (2016) greater pedological processes such as seepage, leaching and pedoturbation and levissage takes place after 30cm soil depth. In the flooded area, the soil samples were labeled D to F. while for the non-flooded areas the soil samples were labeled G to I. For the flooded area the elevation D, E and F are 107 m, 106 m and 116 m above sea levels respectively. While for the non-flooded area, G, H and I are 108 m, 107 m and 119 m above sea levels respectively. The soil colour was determined using a munsell soil colour chart (Revised washable edition of year 2000). For each of the location where the soil samples were collected the flooded areas and the control area, nine soil samples each were collected. Thus, a total of 18 soil samples were collected for the purpose of this study. To prevent mix ups, the soil samples from each sampling points were stored on polythene bags and labeled accordingly and taken to the laboratory. They were air dried, crushed and passed through a 2mm sieve for the determination of selected physical, chemical and biological characteristics. During the collection of soil samples, plant foliage, furrow, compost pits, old manures, rocks, and areas near trees were avoided and excluded. This helped to reduce differences, which may arise because of the dilution of soil organic matter due to mixing through cultivation and also to reduce the stoniness of the soil samples, among other factors (Orobator *et al*., 2018).

Plate 3.1: Control
Source: Author's Fieldwork, 2021

Plate 3.2: Flooded Soil
Source: Author's Fieldwork, 2021.

Plate 3.3: Soil Augering
Source: Author's fieldwork, 2021.

Table 3.1: Location of Sampling Points.

Sampling Points	GPS location of Sampling Points	Elevation (m)	Soil Depth (cm)
Experiment A (Flooded Soils)			
D_1, D_2 and D_3	6°32'33.6"N, 5°37'21.0"E	107	0-15, 15-30 and 30-45
E_1, E_2 and E_3	6°32'41.4"N, 5°37'22.2"E	106	0-15, 15-30 and 30-45
F_1, F_2 and F_3	6°32'49.1"N, 5°37'21.8"E	116	0-15, 15-30 and 30-45
Experiment B (Control /Non-flooded soils)			
G_1, G_2 and G_3	6°32'32.1"N, 5°37’18.9"E	108	0-15, 15-30 and 30-45
H_1, H_2 and H_3	6°32'41.4"N 5°37'12.6"E	107	0-15, 15-30 and 30-45
I_1, I_2 and I_3	6°32'50.8"N 5°37'17.7"E	119	0-15, 15-30 and 30-45

Source: Author's Fieldwork, 2021.

KEY:

1. GPS location of Sampling Points is in Degrees Decimal Minutes (DDM)

2. D_1, D_2 and D_3 = First sampling points, E_1, E_2 and E_3 = Second sampling points F_1, F_2 and F_3 = Third sampling points, G_1, G_2 and G_3 = Fourth sampling points, H_1, H_2 and H_3 = Fifth sampling points, I_1, I_2 and I_3 = Sixth sampling points.

3. The suffixes $_1$, $_2$ and $_3$ are soil depths of 0 – 15, 15 – 30 and 30 – 45 cm respectively.

3.5 Laboratory Soil Sample Analysis

The soil samples taken to the laboratory were analysed for the physico-chemical and biological characteristics as follows:

Bulk density (Bd) and saturated hydraulic conductivity (Ksat) were determined using method according to Grossman and Reinsch (2002). The fractions of sand, silt and clay was determined using hydrometer method (Gee *et al*, 2002) *with* NaOH as dispersant. Total porosity (%) was derived from the relationship of particle density to the bulk density using the formula;

Percentage pore space = (1-Db/Dp) x 100

Where; Db= bulk density and

Dp= particle density.

The average Dp of mineral soils which is 2.65Mgm^{-3} was used for computation.

Water holding capacity was determined by passing crushed air-dried soil through a 2mm sieve. Water was poured into the soil to make it moist and it was then filtered. The weight of the dish and filter paper was noted:

1) Weight of empty dish + filter paper - a gms.

2) Weight of empty dish + filter paper + air dry soil- b gms

3) Weight of empty dish + filter paper+ wet soil - c gms.

It was calculated thus:

$$\text{Saturation Moisture \%} = \frac{(c - a) - (b - a)}{(b - a)} \times 100$$

Soil pH was determined using a 1:1 soil to water suspension using glass electrode pH meter (Mclean, 1982). Available phosphorus was obtained using Bray 11 bicarbonate extraction method as described by Olsen and Sommers (1982). Particle size analysis was determined by hydrometer method using sodium hexametaphosphate as dispersing agent (Okalebo, Gathua and Woomer, 2002). The pH meter was calibrated using pH 7 buffer solution. Then the water was adjusted with known buffer solutions 4.0 and 9.2. Soil weighing 20g was transferred into 100ml beaker. 40ml distilled water was added and stirred well with a glass rod. This was allowed to stand for half an hour with intermittent stirring. The glass electrode was submerged into water suspension in the beaker and pH value was determined and recorded from the automatic display of the pH meter.

Also, the percentage Base Saturation (BS %) was calculated as the sum of the exchangeable base divided by ECEC, multiplied by 100.

Available Zn, Cu, Fe and Mn in the soils were extracted with 0.04 m EDTA and their concentration determined by atomic absorption spectrophotometry (AAS).

Total nitrogen was determined using micro- Kjeldahl method (Bremner and Mulvaney 1982). Soil organic carbon was measured by combustion at 840°C (wet-oxidation method) (Wang, 2004). Exchangeable bases, Ca^{2+} and Mg^{2+} were obtained by ammonium acetate (NH_4 oAc) method, and Na^+ and K^+ by flame photometer. Exchangeable acidity was determined titrimetrically using 0.05 N NaOH.

The determination of soil organic carbon was done by wet dichromatic acid oxidation method (Nelson and Sommers, 1982). A factor of 1.724 was used to multiply organic matter.

In determining Effective Cation Exchangeable Capacity (ECEC), the exchangeable acidity and the total exchangeable bases already determined were added.

ECEC= exchangeable acidity + total exchangeable bases.

Total heterotrophic bacteria and total heterotrophic fungi counts in soil samples were estimated by spreading aliquots (0.1ml) of decimal serial dilutions of the soil samples onto duplicate nutrient agar plates (pH 7.2) into which were incorporated 10 mg/ml fungi-zone to inhibit fungal growth. Fungal counts were determined using potato Dextrose agar (pH 4.5) containing antibiotics (penicillin G, 0.05 g/l; chloramphenicol, 0.5

g/l and streptomycin, 0.025 g/l) to suppress bacterial growth. One gram of soil samples was added aseptically to 9 mls of sterile mineral salts medium. Decimal serial dilutions of the soil samples were subsequently made with sterile mineral salts medium and aliquots (0.1 ml) inoculated on the mineral salts agar surface by the spread plate technique. The bacterial isolates were examined for colonial, morphological and biochemical characteristics according to methods described by Carpenter (1977) and Cruickshank, Duguid, Marmon and Swain (1975). Identification involved the use of the determinative schemes of Buchanan and Gibbons (1974) and Cowan (1974). Fungal isolates were examined macroscopically and microscopically using the needle mounts method. Extrapolation was carried out using standard calibration curve (UNEP, 2009; Millioli, Servulo, Sobral, De Clor and Iho, 2009).

Soil fertility index (SFI) values (Moran, Brodizon, Tucker, Da Silva-Forsberg, McCracken and Falesi, 2000) and soil evaluation factor (SEF) (Lu, Moran, and Mausel 2002) were calculated to quantify soil fertility. The following equations were used to calculate the values (Lu, Moran, and Mausel 2002):

SFI = pH +organic matter (%, dry soil basis) +available P (mg kg^{-1}, dry soil)+exch. K (ceq kg^{-1}, dry soil) +exch. Ca (ceq kg^{-1}, dry soil)+exch. Mg (ceq kg^{-1}, dry soil) −exch. Al (ceq kg^{-1}, dry soil).

SEF = [exch. K (ceq kg^{-1}, dry soil) +exch. Ca (ceq kg^{-1}, dry soil) +exch. Mg (ceq kg^{-1}, dry soil) – log (1 +exch. Al (ceq kg^{-1}, dry soil))] x organic matter (%, dry soil) +5.

3.6 Statistical Analysis

Data collected were analyzed using factorial arrangement in randomized complete block (RCB) design, non-replicated. The permissible limits for selected soil quality indicators as modified by Orobator (2019) are presented in **Table 3.2.**

Table 3.2: Permissible Limits For Some Selected Soil Quality Indications

Soil Parameter	Very Low	Low	Medium	High	Very high
pH		< 5.5	5.5 – 7.0	> 7.0	
OM (g Kg^{-1})		4	4 – 10	> 10	
TOC (g Kg^{-1})		< 1	1 – 5	> 5	
TN (g Kg^{-1})	< 0.1	0.1 – 0.2	0.2 – 0.5	0.5 – 1.0	> 1.0
Avail. P (mg Kg^{-1})		< 8	8 – 20	> 20	
Ca (Cmol kg^{-1})					
Mg (Cmol kg^{-1})		< 3	3 – 8	> 8	
K (Cmol kg^{-1})		0.5	0.5 – 4	> 4	
Na (Cmol kg^{-1})	< 0.1	0.1 – 0.3	0.3 – 0.7	> 0.7 – 2	> 2
ECEC (Cmol kg^{-1})	< 5	5 – 15	15 – 25	25 – 40	> 40
BS (%)	20	20 – 40	40 – 60	60 – 80	> 80
Fe (mg Kg^{-1}		< 0.1	1 – 10	> 10	
Mn (mg Kg^{-1})	< 1	1 – 10	10 – 100	> 100	
Zn (mg Kg^{-1})		1	1 – 10	10	
Cu (mg Kg^{-1})		< 0.4	0.4 – 0.6	> 0.6	

Adapted From SPFS (2004) Ugwa *et al.*, (2016), Orobator (2019)

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 The Sites

The experimental site was generally saucer–shaped. Similarly, the sites having upper, middle and lower slope are revealed in **Table 4.1;** flooded area and a non–flooded area**.** The saucer shaped depression is without any outlet and as such fine sediment seemed to accumulate in it. The reason for the saucer shape perhaps, is that soils in Edo South of Nigeria have more clay accumulation at top soils. Besides, the location is erosive due to the high annual rate of rainfall, not only on uplands but also on floodplains. The notion that only all flooded areas, and indeed floodplains are homogeneous is apparently mistaken (Hoag, Buol and Perez, 1987). The morphological and chemical characteristics of the soil are therefore confined to differ due to the different sources of material and terrain in which they are found. The rain falls all the year round except during the dry spell within the month of August which perhaps may be regarded as a slight drought.

Okeoma and Yadev (1982) reported that slight drought occurs when there is $\leq$20% of the long term effect of the annual rainfall for a given year. In the wet season, rainfall exceeds the evapo-transpiration making the runoff and percolation occur in the depressed areas. This may be due to the frequent, erosive and high interactive nature of the rain. The annual temperature is sufficient in the deposition of organic matter.

TABLE 4.1 MORPHOLOGICAL CHARACTERITICS OF SOILS OF THE STUDY AREA

Soil Sample	Elevation (m)	Physiography	Depth (cm)	Colour (moist)	Soil structure	Consistency (moist)	Roots	Mottles
				FLOODED SOILS				
D_1	107	Middle Slope	0 – 15	7.5YR 3/4 (dark brown)	1, 2, Gr	F	Fi, Fe	Nil
D_2			15 – 30	5YR 3/3 (dark reddish brown)	2, C, Abl	F	Fi, Fe	Fi, Fe, Fa
D_3			30 – 45	5YR 3/2 (dark reddish brown)	2, C, Abl	F	Fi, Fe	Nil
E_1	106	Lower Slope	0 – 15	7.5YR 2.5/3 (very dark brown)	1, C, Abl	F	C, M	Nil
E_2			15 – 30	5YR 3/3 (dark reddish brown)	1, C, Bl	L	Fi, Fe	Fa, Fe, Fi
E_3			30 – 45	10R 3/4 (dusky red)	2, F, Abl	Fr	Fi, Fe	Fe, C, Di,
F_1	116	Upper Slope	0 – 15	2.5YR 3/4 (dark reddish brown)	2, F, Gr	F	C, M	Nil
F_2			15 – 30	2.5YR 2.5/4 (dark reddish brown)	2, F, Gr	Fr	Fi, M	Nil
F_3			30 – 45	2.5R 3/6 (dark red)	2, Me, Bl	F	Fi, F	Di, Me, Co
				NON-FLOODED SOILS				
G_1	108	Middle Slope	0 – 15	2.5YR 3/3 (dark reddish brown)	1, 2, Gr	Fr	Fi, Fe	Nil
G_2			15 – 30	5YR 3/4 (dark reddish brown)	1, 2, Gr	F	Fi, Fe	Nil
G_3			30 – 45	5YR 3/3 (dark reddish brown)	1, 2, Abl	F	Fi, Fe	Nil

H_1	107	Lower Slope	0 – 15	5YR 3/2 (dark reddish brown)	1, 2, Gr	F	Fi, M	Nil	
H_2			15 – 30	2.5YR 3/4 (dark reddish brown)	1, 2, Gr	F	Fi, Fe	Nil	
H_3			30 – 45	2.5YR 2.5/3 (dark reddish brown)	2, C, Gr	F	Fi, Fe	Nil	
I_1	119	Upper Slope	0 – 15	7.5YR 3/3 (dark brown)	1, C, Abl	L	C, M	Fa, Fe, Co	
I_2			15–30	5YR 3/4 (dark reddish brown)	1, C, Abl	L	C, Fi, M	Nil	
I_3			30 – 45	10R 3/2 (dusky red)	1, C, Bl	F	C, M	Nil	

Key;
Structure: 1= Weak, 2 = Medium, Abl = Angular blocky, Bl = Blocky, C = Coarse, F = Firm, Gr = Granular

Consistency: F = Firm, Fr= friable, L = Loose

Texture: LS = Loamy Sand, SL = Sandy Loam

Roots: Fi = Fine, C = Coarse, Fe = Few, M = Many

Mottles: C = Coarse Co = Common Di = Distinct Fa = Faint Fe = Few F = Fine Me = Medium

4.2 Morphological Properties

The morphological properties are also shown in **Table 4.1**.The structure of the soils in the study area is varied. The dominant structure in the flooded soils is weak, medium, coarse and angular blocky. On the other hand, the structure of the non-flooded soils is mostly granular, firm and medium.

The soils of the study area do not have the same colour but predominantly brown colouration. The implication of this is that the soil colour can be related to specific properties of the soil (Ugwa et al., 2016). The soils therefore have varied colours. Biswas and Mukherjee (1994) and Soil Survey Staff (2014) observed that red and yellow colour indicates the presence of free iron oxides common in well oxidized soil, while organic matter present indicates brown and dark colouration. The hue is mostly a mixture of 2.5YR and 5YR stipulating the dominant spectral colour of the soils of the area. The colour value in both the flooded and non-flooded is 3 indicating the dark nature of the soils.D1 has a dark brown colour (7.5YR 3/4, moist),D2 is dark reddish brown (5YR 3/3, moist), D3 is also dark reddish brown (5YR 3/2, moist), E1 is very dark brown (7.5YR 2.5/3, moist), E2 is dark reddish brown (5YR 3/4, moist), E3 is dusky red (10R 3/4, moist) F1 is dark reddish (2.5YR 3/4, moist), F2 is dark reddish brown (2.5YR 2.5/4, moist), F3 is dark red (2.5R 3/6, moist), G1 is dark reddish brown (2.5YR 3/3, moist), G2 is dark reddish brown (5YR 3/4, moist), G3 is dark reddish brown (5YR 3/3, moist), H1 is dark reddish brown (5YR 3/2, moist),H_2 is dark reddish brown (2.5YR 3/4, moist), H_3 is dark reddish brown.(2.5YR 2.5/3, moist), I_1 is dark brown (7.5YR 3/3, moist), I_2 is dark reddish brown (5YR 3/4, moist) and I_3 is dusky red (10R 3/2, moist).

The soil consistency (moist) in the area of study varies from loose, firm to friable. The firm consistency suggests that the soil anchors plants appropriately. The loose to weak cohesion in the subsoil of flooded and non-flooded area shows the sandy nature of the soil fraction. The texture of the soils in both the soils in the flooded and non–flooded areas was mostly sandy loam. It differed only in D_1, G_1, H_1 and I_1 (upper slopes) where there are loamy sand. This suggests that, the upper top soils values which have more of organic felt the impact of organic matter more than the lower top-soils. A loamy sandy soil is usually loose, excessively drained and retain little water and nutrient for plant growth. It has very high permeability to downward water movement because of its loose structure (Soong and Lau, 1977). For the flooded area, the roots for D_1 to E_3 were generally fine and few, with only E_1 (flooded, middle slope) that the roots were coarse and many. F_1 is coarse and many. The roots in the flooded area were that of weeds. For the non–flooded part of the area, the roots of $G_1$to G_3 were fine and few, H_1 is fine and many, H_2 and H_3 is fine and few. The roots of the subsoil of non-flooded area (I_2) had unique root which is Coarse and fine and many. The root of $I_1$and I_3 is coarse and many. The reason for this kind of root is because the study was done under an oil palm plantation with centrosema grasses and few shrubs scattered around. There was soil fauna and anthropogenic activities around the area. There was also the presence of anthills, climbers, ephiphytes and parasitic plants by the sides of most of the oil palm trees indicating faunal pedoturbation. There was evidence of mottles in some of the soils. The mottles were few and faint in the flooded area. The mottles according to Esu (1999) and Ugwa et al., (2016) might likely be as a result of redox condition in the soil matrix.

4.3. Soil Physical Properties

Table 4.2 shows the physical characteristics of the soil in both the flooded and non-flooded areas. The distribution of the sand fraction ranges from 650 to 900 gkg-1. There is therefore more preponderance of sand in the fractions. This reflects the dominance of quartz in the parent material. The soil fractions in this study occur in the order of sand > silt > clay. Soils that are high in sand content tend to have a lower available water capacity (soil Survey Staff, 1999). The silt fraction ranges from 50 to 250 gkg-1. The clay fraction is the smallest it ranges from 50 to 180 gkg^{-1}. Soong and Lau (1977) have indicated that based on the different combinations of sand, silt and clay, soil texture is grouped into various textural classes. Silt and sand fractions, according to Biswas and Mukherjee (1994) are partially weathered primary minerals and the physically most inert. Silt is often micro-sand. The clay and silt contents of the soils increased with soil depth in all the locations with the highest clay content in the non-flooded area H_3 (180 gkg-1). The low clay content at the surface soil (0 – 15 cm) may be due to the sorting of soil materials by biological activities or clay migration, leaching or combination of some of the soil processes. This low clay content in the epipedon (surface soils) is in line with the report of Ubuoh *et al.,* (2016) and Ugwa *et al.,* (2016). The bulk density values indicate that the soil was compact as they were generally high and ranged from 1.38 – 1.61 Mg m^{-3}. In comparison of the flooded area with the non-flooded area, the bulk density of the former generally decreases with depth whereas in the latter, it seems it has no definite pattern. It is surprising therefore that the bulk density decreased with depth in the flooded area. Ogban and Edoho (2011) were of the opinion that bulk density is higher in the subsoil (endopedon) as a result of compaction caused by weight of the overlying soils. The low values of the bulk density at the endopedon may be attributed to relative high value of the organic matter. The porosity value was high (39.24 – 47.92%) and it has an inverse relationship with the soil bulk density. This means that as the bulk density values increase, the porosity values also decreases and vice-versa. The water holding capacity (WHC) for both the soils in the flooded and the non-flooded areas ranges from 30 – 36% with H_3 (subsoil of the non-flooded area)having the lowest value of 30% while D_3, E_2, f_1, F_2, F_3, G_1 and H_1 have the highest value of 36%. This implies that, the soil samples listed retain more water than most of the soil samples. The moisture content of this area is never frozen or usually dry. It is therefore moist and the soil is saturated with water within the depth of the root zone. The hydraulic conductivity

(Ksat) ranges from 5.8-7.2(10-6 ms-1) with D1, G1 and I1 having the lowest values and F1, F3, G3, H2, I2 and I3 having the highest values.

The silt/clay ratio of the flooded area ranged from 0.67 to 5 whereas that of non-flooded area was 0.5 to 3.0 showing that the latter ratio had lower weathering intensity than the former. Ayolagha (2001) reported that silt/clay ratio of > 0.15 indicated low weathering intensity. This implies that the pluvial flooding has no negative effect in the weathering index. It has been suggested that the ratio between exchangeable Ca to exchangeable Mg (Ca/Mg) values in the top 15 cm of the soil should not exceed 4.0 (Hardy, 1971). Generally, the Ca/Mg ratio that is <4.0 is less in the non-flooded area and according to Hardy (1971), the Ca/Mg ratio being an index of soil structural stability does not show any weathering status loss of much colloidal material in the formation of soil aggregates and exposure to soil degradation.

Tables 4.3, 4.4, 4.5, 4.6 and 4.7 show the relationship between some selected physical characteristics and treatment such as the nature of soil (flooded and non – flooded), location and depth.

Table 4.3 reveals that sand particle in the non-flooded soil has a higher value than the flooded soil and significantly different (P>0.05). Silt is higher in the flooded soil,

TABLE 4.2: PHYSICAL CHARACTERISTICS OF SOILS OF THE STUDY AREA

Soil Sample	Location	Elevation (m)	Depth (cm)	Clay (g kg^{-1})	Silt (g kg^{-1})	Sand (g kg^{-1})	Silt/Clay Ratio	Texture	B.D (Mg m^{-3})	Total Porosity (%)	WHC (%)	H.C (10^{-6} ms^{-1})	ca/mg ratio
FLOODED SOILS													
D_1	N6°32’33.6’’ E5°37’21.0”	107	0 – 15	50	100	850	2.00	LS	1.56	41.13	32	5.8	4.08
D_2			15 – 30	50	250	700	5.00	SL	1.61	39.24	32	7.0	4.08
D_3			30 – 45	100	100	700	2.00	SL	1.42	46.41	36	7.0	4.14
E_1	N6°32’41.4’’ E5°37’22.2’’	106	0 – 15	50	250	700	5.00	SL	1.38	47.92	34	7.0	4.14
E_2			15 – 30	50	250	700	5.00	SL	1.42	46.41	36	7.0	4.10
E_3			30 – 45	100	100	700	2.00	SL	1.42	46.41	34	7.0	4.44
F_1	N6°32’49.1” E5°37’21.8’’	116	0 – 15	100	100	800	1.00	SL	1.47	44.52	36	7.2	4.44
F_2			15 – 30	150	200	650	1.33	SL	1.51	43.01	36	6.9	2.76
F_3			30 – 45	150	100	750	0.67	SL	1.42	46.41	36	7.2	5.13
NON FLOODED SOILS													
G_1	N6°32’32.1’’ E5°37’18.9”	108	0 – 15	50	100	850	2.00	LS	1.42	46.41	36	5.8	3.10
G_2			15 – 30	100	200	700	2.00	SL	1.47	44.52	32	7.0	5.45
G_3			30 – 45	100	50	850	0.50	SL	1.42	46.41	32	7.2	3.45
H_1	N6°32’41.4’’	107	0 – 15	100	100	900	1.00	LS	1.42	46.41	36	6.0	6.55

	E5°37’12.6”												
H_2			15 – 30	150	100	750	0.67	SL	1.47	44.52	32	7.2	2.05
H_3			30 – 45	180	100	720	0.56	SL	1.42	46.41	30	7.I	7.21
I_1	N6°32’30.8 E5°37’ 17.7”	119	0 – 15	50	150	800	3.00	LS	1.42	46.41	32	5.8	2.65
I_2			15–30	100	200	700	2.00	SL	1.42	46.41	32	7.2	4.55
I_3			30 – 45	100	250	650	2.50	SL	1.38	47.92	36	7.2	4.10

Key; D: Depth Texture L: Location LS = Loamy Sand NS: Nature of Soil SL = Sandy Loam

TABLE 4.3: SOME PHYSICAL CHARACTERISTICS OF SOILS OF THE STUDY AREA

Treatment	Particle size (g kg^{-1})			Silt/Clay	B.D	Porosity	WHC	HC
	Sand	Silt	Clay	ratio	(mg cm^{-3})	(%)	(%)	(10^{-c} ms^{-1})
Nature of soil								
Flooded soil	706b	183.00a	88.85b	2.56a	1.47a	44.60b	34.67a	6.96a
Non-Flooded soil	769a	138.89b	103.33a	1.58b	1.43b	46.21a	33.11b	6.72b
LSD (0.05)	46.2	0.555	0.544	0.392	0.016	0.157	0.563	0.088
Location								
D	742	149.94b	75.00c	2.25a	1.49a	44.02c	33.33b	6.73b
E	745	166.67a	104.94b	2.21b	1.42b	46.34a	33.67b	6.88b
F	725	166.67a	108.33a	1.75c	1.44b	45.85b	34.67a	6.92a
LSD (0.05)	ns	0.679	0.666	0.480	0.020	0.193	0.689	0.105
Depth (cm)								
0 – 15	783a	133.33c	66.67c	2.17b	1.44b	45.50b	34.33a	6.27b
15 – 30	700b	199.94a	99.94b	2.67a	1.50a	44.00c	33.33b	7.14a
30 – 45	728ab	150.00b	121.67a	1.37c	1.41c	46.76a	34.00a	7.12a
LSD (0.05)	56.3	0.679	0.666	0.480	0.020	0.193	0.689	0.105
NS X L	78.2	0.961	0.942	0.679	0.028	0.272	0.975	ns
NS X D	ns	0.961	0.942	0.679	0.034	0.272	0.975	0.149
L X D	ns	1.177	1.153	0.832	0.034	0.333	1.194	0.182

NS X L X D	ns	1.664	1.631	1.176	0.049	0.472	1.689	0.257

D: Depth L: Location NS: Nature of Soil ns: Not significant at 0.05 level of probability.

P >0.05 = significantly different

P < 0.05 = Not significantly different

Means followed by common letters are not significantly different

significantly different ($P>0.05$). Clay is higher and significantly different ($P>0.05$) in the non-flooded soil than flooded soil. The silt/clay ratio for the non-flooded soil is lesser when compared with that of the flooded area ($P>0.05$) indicating that the soils have not been subjected to severe weathering with a lot of weatherable minerals. Bulk Density is higher in the flooded soil and it is significantly different ($P<0.05$) with non-flooded soil. It also has an inverse relationship with total porosity. Nelson and Terry (1996) stated that bulk density can be changed by soil management that affect organic matter and improves soil porosity. The internal drainage of the soils on the non-flooded area may have to be improved. The Water Holding Capacity (WHC) and Hydraulic Conductivity (ksat) value were higher in the flooded soil and also significantly different ($P>0.05$) with the non-flooded soil. The soils have no saturated hydraulic conductivity by moderately fine features in the non-flooded area. When treated with locational differences, soil depth has no effect on the sand fraction, but other soil physical parameters have significant difference ($P>0.05$) in all the locations **(Table 4.2).** Also, there is no interaction between sand with flooded and non-flooded soils (NS X L X D).

TABLE 4.4: INTERTACTIVE EFFECT OF NATURE OF SOIL AND LOCATION ON SOME PHYSICAL CHARACTERISTICS OF SOILS THE OF STUDY AREA

Nature of soil	Location	Particle Size (g kg^{-1})			silt/Clay ratio	B.D	Porosity	WHC
		Sand	Silt	Clay		(mg kg^{-1})	(%)	(%)
Flooded Soil								
D	(N6°32'33.6'' E5°37'21.0'')	683b	183.22c	66.67d	3.00a	1.55a	42.26d	33.33c
E	(N6°32'41.4'') E5°37'22.2'')	700b	233.33a	66.56d	3.67a	1.40c	46.89a	34.67b
F	(N6°32'49.1'') E5°37'21.8'')	33ab	133.33d	133.33a	1.00c	1.47b	44.65c	36.00a
Non – Flooded Soil								
G	(N6°32'32.1'') E5°37'18.9'')	800a	116.61e	83.33c	1.50c	1.44b	45.78b	33.33c
H	(N6°32'41.4'') E5°37'12.6'')	790a	199.94b	143.33d	0.74d	1.44b	45.78b	32.67d
I	(N6°32'30.8'' E5°37' 17.7'')	7 17b	133.33d	83.33c	2.50b	1.41c	47.06a	33.33c
LSD (0.05)		78.2	0.961	0.942	0.679	0.028	0.272	0.975

When treated with Nature of soil (Flooded and non-flooded soils) and locations of some physical characteristics, **Table 4.4** revealed that sand particles in the non flooded soil in location G to I are more in values than the flooded area, and also it is significantly different (P>0.05) than the other locations. Silt and clay particles are higher in values in the flooded soil (E and F) it is significantly different (P>0.05). The silt/clay ratio is higher in the flooded soil and especially in location D and F. This implies the ability of the soil to withstand some erosion processes. Bulk density has a high value in the flooded soil(location D) (P <0.05): any value above 1.80 Mg kg^{-1} makes the soil somewhat root-limiting. It can be attributed to the high volume of water that has made the pore spaces of the soil very compacted (Biswas and Murkherjee, 1994). The Porosity value is highest and significant in the non-flooded soil (location I) and significant too showing that when bulk density is low the total porosity is high. The water holding capacity (WHC) is higher in the flooded soil; location F, implying the ability of the soil to be able to hold more water than other locations.

It is at 15 – 30 cm soil depth and indeed, in the non-flooded soils that silt and clay were significant **(Table 4.5).** This phenomenon may be due to the sorting out of soil materials or perhaps, the elluviation of the soil processes. Silt/clay ratio value was higher in the flooded soil; at depth 15 – 30 cm. The hydraulic conductivity value was high and

TABLE: 4.5 INTERACTIVE EFFECT OF NATURE OF SOIL AND DEPTH ON SOME PHYSICAL CHARACTERISTICS OF THE SOIL OF THE STUDY AREA

Nature of soil	Depth (cm)	Particle Size Silt	Clay	Silt/Clay	B.D (Mg cm^{-3})	Porosity (%)	H.C (10^{-6} m-s)	W.H.C (%)
Flooded Soil	0 – 15	149.94d	66.67d	2.33b	1.46b	44.52d	6.67b	34.00b
	15 – 30	166.67b	66.56d	3.78a	1.54a	42.89d	7.16a	34.67ab
	30 – 45	166.67b	133.33b	1.57c	1.42c	46.39b	7.07a	35.33a
Non – Flooded Soil	0 – 15	133.33e	83.33c	2.00bc	1.42c	46.37b	5.87c	34.67ab
	15 – 30	199.94a	143.33a	1.56c	1.45b	45.11c	7.13a	32.00c
	30 – 45	150.00c	83.33c	1.19cd	1.41c	47.14a	7.17a	32.67c
LSD (0.05)		0.961	0.942	0.679	0.028	0.272	0.149	0.975

D: Depth L: Location NS: Nature of Soil ns: Not significant at 0.05 level of probability.

P >0.05 = significantly different

P < 0.05 = Not significantly different

Means followed by common letters are not significantly different

significant in the sub-soils of the study area indicating the movement of water through the soil. Hydraulic conductivity depends on texture and structure. Water holding capacity value was high in the flooded soil at depth 30 – 45 cm and indicated significant difference (P>0.05). Sand grains are large and internal surface areas are low so much that it holds less water against gravity.

Table 4.6 reveals the interactive effect of some physical properties such as particle size (silt and clay), silt/clay ratio, bulk density, porosity, hydraulic conductivity and water holding capacity when treated with Locations and depths was significantly different (P >0.05).

The effect of nature of soil, location and depth on particle size (silt and clay), silt/clay ratio, bulk density, porosity, hydraulic conductivity and water holding capacity in **(Table 4.7)** is significantly different (P>0.05).

TABLE: 4.6 INTERACTIVE EFFECTS OF LOCATION AND DEPTH ON SOME PHYSICAL CHARACTERISTICS OF SOILS OF THE STUDY AREA

Location	Depth (cm)	Particle Size ($g\ kg^{-1}$) Silt	clay	Silt/Clay ratio	B.D ($mg\ cm^{-3}$)	Porosity (%)	H.C (10^{-6} m-s)	W.H.C (%)
D_1	0 – 15	100.00e	50.00e	2.00	1.49b	43.77e	5.80c	34.00b
D_2	15 – 30	224.83a	75.00d	3.50	1.57a	41.88f	7.28a	32.00c
D_3	30 – 45	125.00e	100.00c	1.25	1.42cd	46.41b	7.10a	34.00b
E_1	0 – 15	175.00c	75.00d	2.50	1.39d	47.17a	6.50b	35.67a
E_2	15 – 30	175.00c	99.83c	2.84	1.45c	45.47c	7.10a	34.00b
E_3	30 – 45	150.00d	140.00a	1.28	1.42cd	46.38b	7.05a	32.00c
F_1	0 – 15	125.00e	75.00d	2.00	1.44cd	45.41c	6.50b	34.00b
F_2	15 – 30	200.00b	125.00b	1.67	1.47bc	44.64d	7.05a	34.00b
F_3	30 – 45	175.00c	125.00b	1.59	1.40d	47.50a	7.20a	32.67c
LSD (0.05)		1.177	1.153	0.831	0.034	0.333	0.182	1.194

D: Depth L: Location NS: Nature of Soil ns: Not significant at 0.05 level of probability.

P >0.05 = significantly different

P < 0.05 = Not significantly different

Means followed by common letters are not significantly different

TABLE 4.7: INTERACTIVE EFFECT OF NATURE OF SOIL, LOCATION AND DEPTH ON PHYSICAL CHARACTERISTICS OF SOILS OF THE STUDY AREA

Nature of soil	Soil Sample	Location	Depth	Particle Size		Silt/Clay	B.D	Porosity	H.C	W.H.C
				Silt	Clay	ratio	(mg kg^{-1})	(%)	(10^{-6} m-s)	(%)
Flooded Soil	D_1	N6°32'33.6'' E5°37'21.0	0 – 15	100.00d	50.00d	2.00cd	1.56a	41.13f	5.80d	32.00c
	D_2		15 – 30	249.67b	50.00d	5.00a	1.68a	39.24g	7.57a	32.00c
	D_3		30 – 45	200.00b	100.00c	2.00cd	1.42c	46.41c	7.00bc	36.00a
	E_1	N6°32'41.4'' E5°37'22.2''	0 – 15	250.00a	50.00d	4.00ab	1.36e	47.92b	7.00bc	34.00b
	E_2		15 – 30	250.00a	49.67d	5.00a	1.43c	46.41c	7.00bc	36.00a
	E_3		30 – 45	200.00b	100.00c	2.00cd	1.42c	46.34c	7.00bc	34.00b
	F_1	N6°32'49.1" E5°37'21.8''	0 – 15	100.00d	100.00c	1.00d	1.47c	44.52d	7.20b	36.00a
	F_2		15 – 30	200.00b	150.00b	1.33d	1.51bc	43.01e	6.90c	36.00a
	F_3		30 – 45	100.00d	150.00b	0.67e	1.42d	46.41c	7.20b	36.00a
Non–Flooded Soil	G_1	N6°32'32.1'' E5°37'18.9''	0 – 15	100.00d	50.00d	2.00cd	1.42d	46.41c	5.80d	36.00a
	G_2		15 – 30	200.00b	100.00c	2.00cd	1.47c	44.52d	7.00bc	32.00c

G_3		30 – 45	50.00e	100.00c	0.50e	1.42d	46.41c	7.20b	32.00c
H_1	N6°32'41.4'' E5°37'12.6''	0 – 15	100.00d	100.00c	1.00de	1.42d	46.41c	6.00c	36.00a
H_2		15 – 30	100.00d	150.00b	0.67e	1.47c	44.52d	7.20b	32.00c
H_3		30 – 45	100.00d	180.00a	0.56e	1.42d	46.41c	7.10bc	30.00d
I_1	N6°32'30.8'' E5°37' 17.7''	0 – 15	150.00c	50.00d	3.00bc	1.42d	46.30c	5.80d	32.00c
I_2		15 – 30	200.00b	100.00c	2.50c	1.42d	46.28c	7.20b	32.00c
I_3		30 – 45	50.00e	100.00c	2.50c	1.38e	48.59a	7.20b	36.00a
LSD (0.05)			1.664	1.631	1.176	0.049	0.472	0.257	1.689

D: Depth L: Location NS: Nature of Soil ns: Not significant at 0.05 level of probability.

P >0.05 = significantly different

P < 0.05 = Not significantly different

Means followed by common letters are not significantly different

4.4. Soil Chemical Characteristics

The soil chemical characteristics of the study area are presented in **Table 4.8.** The result showed that the pH values of the soils in the flooded and the non-flooded areas were all acidic. The top soils in both the flooded and non–flooded areas ranges from 6.0 to 6.6. The soils of $D_1$to D_3 were not really acidic with pH values of 6.6, 6.6 and 6.5 respectively. Only the pH values of the soil samples H_1 to H_3 remained constant with the pH value of 6.0. The permissible limit for pH fell within the medium range **(see Table 3.2).** The acidic nature of the soil may not pose any danger to crop production. Tree crops in Nigeria thrive better in soil with such range of pH (Esekhade, Orimoloye, Ugwa and Idoko 2003).

The organic carbon gives an estimate of the organic matter in the mineral soil (Buol *et al,* 1973). Its values ranged from 1.30to 2.90g kg^{-1} with the lowest value for I_2 and the highest for D_1. This falls under the medium range **(see Table 3.2)**. A good relationship between organic carbon and total nitrogen has been established by Brady (2002). They are reciprocal. It is expected that the nature of the water logging will increase the values of organic matter caused by the slow rate of decomposition. The total nitrogen ranges from 0.20 to 0.40 gkg^{-1}. The variation in total N below the sites follows the same pattern as that of organic matter content. The moderate value of total N may be due to the presence of oil palm trees or perhaps the leguminous ground cover in the study area.

Phosphorus is an important micronutrient needed in a considerable amount for plant growth. The phosphorus value for this experiment ranged from 0.48 $mgkg^{-1}$ for I_2 to 1.10 $mgkg^{-1}$ for D_1. The available phosphorus in all the soil samples is very low when compared with the critical value of 15mg kg^{-1} (Adiakwu and Ali, 2013). Phosphorus is aproblem nutrient in the soil and indeed, it is highly fixed and readily unavailable to crops (Esu,1996, Ugwa Umweni and Bakare 2016). Brady (2002) emphasized that when fertilizers and manures are added to the soil, the phosphorus are changed to unavailable form and with time becomes highly insoluble.

The soils effective cation exchange capacity (ECEC) ranges from 2.37 to 4.66 Cmol kg^{-1}. There is no specific pattern of its occurrence in the soils. The values of the exchangeable cations (Ca, Mg, K and Na) are also presented in **Table 4.8.** They cannot be high in value but are influenced by the soil parent materials and organic matter. It may also be due to the high rate of rainfall prevalent in the area subjecting the soil to excessive leaching. The base saturation tested for the soil samples are higher than 80% and according to the permissible limit shown in **table 3.2**, it is rated very high. Apart from Fe that shows the highest amount in the soil samples of the study area, the other available micronutrient seems to be low. They range in value as Fe>Zn>Mn>Cu.

TABLE 4.8 CHEMICAL CHARACTERISTICS OF THE SOILS OF THE STUDY AREA

Soil Sample	Depth (cm)	PH (H_2O)	O C (g kg^{-1})	TN (g kg^{-1})	Avail. P (mg kg^{-1})	E.A (Cmol kg^{-1})	Ca	M g	K	Na	ECEC	BS (%)	Mn (mg kg^{-1})	Fe	Cu	Zn
FLOODED SOIL																
D_1	0 – 15	6.6	2.90	0.40	1.10	0.01	2.00	0.49	0.23	0.17	2.90	99.66	2.80	35.8	0.60	12.2
D_2	15 – 30	6.6	1.90	0.30	0.83	0.01	2.00	0.49	0.24	0.17	2.90	99.66	2.80	36.1	0.70	12.4
D_3	30 – 45	6.5	2.10	0.40	0.96	0.01	2.40	0.58	0.28	0.24	3.52	99.52	2.60	44.6	0.74	13.6
E_1	0 – 15	6.2	1.90	0.30	0.84	0.01	2.40	0.58	0.29	0.24	3.52	99.52	2.40	36.5	0.85	14.0
E_2	15 – 30	6.2	1.80	0.20	0.74	0.01	3.20	0.78	0.35	0.25	4.59	99.78	2.40	54.9	0.80	13.8
E_3	30 – 45	5.9	1.70	0.20	0.58	0.01	2.40	0.54	0.26	0.19	3.40	99.71	1.50	50.5	0.94	15.1
F_1	0 – 15	6.4	1.60	0.20	0.52	0.01	2.40	0.58	0.29	0.22	3.50	99.71	2.80	69.3	0.92	14.4
F_2	15 – 30	6.4	1.60	0.20	0.53	0.01	1.60	0.39	0.20	0.17	2.37	99.58	2.70	62.8	0.90	14.0
F_3	30 – 45	6.1	1.80	0.20	0.71	0.01	2.00	0.58	0.28	0.22	3.09	99.68	2.40	68.4	0.80	14.5
NON FLOODED SOILS																
G_1	0 – 15	6.6	1.70	0.40	0.60	0.01	1.80	0.44	0.22	0.20	2.67	99.63	2.80	54.2	0.86	14.8
G_2	15 – 30	5.8	1.60	0.30	0.49	0.01	2.40	0.58	0.29	0.22	3.50	99.71	1.80	48.9	1.20	10.5
G_3	30 – 45	5.8	1.60	0.40	0.50	0.01	2.00	0.49	0.24	0.21	2.95	99.66	2.00	50.1	1.20	12.2
H_1	0 – 15	6.0	2.10	0.30	0.94	0.01	3.21	0.78	0.36	0.30	4.66	99.79	2.70	40.3	0.80	14.5
H_2	15 – 30	6.0	1.40	0.20	0.49	0.01	1.60	0.39	0.20	0.17	2.37	99.58	2.80	56.2	0.90	14.9

H_3	30 – 45	6.0	1.80	0.20	0.71	0.01	2.81	0.68	0.32	0.28	4.10	99.76	2.80	72.6	0.80	15.0
I_1	0 – 15	6.3	2.00	0.20	0.81	0.01	1.80	0.44	0.22	0.19	2.66	99.62	2.20	30.5	0.84	12.2
I_2	15 – 30	6.2	1.30	0.20	0.48	0.01	2.00	0.49	0.25	0.20	2.95	99.66	1.50	38.6	0.94	14.1
I_3	30 – 45	6.2	1.60	0.20	0.50	0.01	2.00	0.49	0.25	0.19	2.94	99.66	1.50	40.8	0.90	14.5

According to Amhakhian and Osenwota (2012), the critical values of the available micronutrient are Fe (5.0 mg kg-1), Mn (2.5 mg kg-1), and Cu (2.0 – 3.0 mg kg-1). Zn is said to be high in the soils and may be prone to toxicity in the soil. Deficiencies in micronutrient are attributed to the nutrient imbalance by heavy depletion of basic cation and phosphorus in the soil complex. The deficiency may not be due to high pH values. Brady (2002) is of the opinion that the micronutrients cations are most soluble and more available under acid conditions. However, this may be somewhat toxic to some plants.

In Table 4.9 treatment with nature of soil and some of the chemical characteristics shows that the pH and organic carbon (O.C) value of the flooded soil was higher than the non-flooded soil, there was significant difference ($P>0.05$). Total nitrogen (T.N) was higher in the non-flooded soil; it was not significant at 0.05 level of probability. Available phosphorus, calcium, magnesium, and sodium were higher in the flooded soil except potassium; the relationship was not significant at 0.05 level of probability. LSD of exchangeable acidity, effective cation exchange capacity (ECEC) and Base percentage indicates not significant at 0.05 level of probability. For the micro element, Fe, Mn and Zn was higher in the flooded soil, it was significantly different ($P>0.05$) except Zn which was not significant at 0.05 level of probability. Only Cu was high in the non-flooded soil and was not significantly different ($P>0.05$). Treatment with location showed that pH for location D and F is high, there was significant difference

TABLE 4.9: SOME CHEMICAL CHARACTERISTICS OF THE SOILS OF THE STUDY AREA

Treatment	pH	O.C	T.N	Avail. P	Exchangeable Cation (Cmol kg^{-1})				E.A	ECEC	B.S	Micro – element (mg kg^{-1})			
	(1:1 H_2O)	(g kg^{-1})		(mg kg^{-1})	Ca	Mg	k	Na	(Cmol Kg^{-1})		(%)	Cu	Fe	Mn	Zn
Nature of Soil															
Flooded Soil	6.32a	1.93a	0.28b	0.68	2.32	0.55	0.27	0.21	0.01	3.38 b	99.60	0.81b	50.99a	2.50a	13.76
Non – Flooded Soil	6.12b	1.67b	0.33a	0.62	2.23	0.53	0.27	0.24	0.01	3.31b	98.94	0.92a	47.78b	2.21b	13.71
LSD (0.05)	0.056	0.054	ns	ns	ns	ns	ns	ns	ns	ns	ns	0.069	0.465	0.064	ns
Location															
D	6.32a	1.98a	0.37	0.76a	2.26b	0.51b	0.25a	0.20	0.01	3.32b	99.54	0.88	48.93b	2.45a	12.62b
E	6.05b	1.78b	0.25	0.66b	2.59a	0.59a	0.30a	0.24	0.01	3.77a	9 9.69	0.85	51.51a	2.43b	14.55a
F	6.28a	1.64	0.29	0.53c	1.97c	0.52b	0.24b	0.23	0.01	3.03c	98.49	0.86	51.72a	2.18c	14.03b
LSD (0.05)	0.081	0.067	ns	0.088	0.272	0.062	0.025	ns	ns	0.103	ns	ns	0.569	0.078	0.135
Depth (cm)															
0 – 15	6.37a	2.03a	0.40	0.79	2.21	0.57	0.26	0.22	0.01	3.31b	98.54	0.78b	44.47c	2.60a	13.68b
15 – 30	6.20b	1.60c	0.25	0.57	2.26	0.54	0.27	0.23	0.01	3.21b	99.67	0.91a	49.20b	2.33b	13.26c
30 – 45	6.08c	1.78b	0.27	0.60	2.35	0.51	0.27	0.23	0.01	3.50a	99.60	0.90a	54.49a	2.13c	14.26a
LSD (0.05)	0.081	0.066	ns	0.088	ns	ns	ns	ns	ns	0.105	ns	0.084	0.569	0.078	0.135
NS X L	0.114	0.094	ns	0.125	ns	ns	ns	ns	ns	0.145	ns	0.119	0.805	0.111	0.111
NS X D	0.114	0.094	ns	ns	ns	ns	ns	ns	ns	0.145	ns	0.119	0.805	0.111	0.191

L X D	0.140	0.114	ns	ns	ns	0.088	ns	ns	ns	0.178	ns	ns	0.986	0.136	0.234
NS X D X L	0.198	0.162	ns	ns	ns	0.108	ns	0.110	ns	0.252	ns	ns	1.394	0.192	0.331

D: Depth L: Location NS: Nature of Soil ns: Not significant at 0.05 level of probability.

P >0.05 = significantly different

P < 0.05 = Not significantly different

Means followed by common letters are not significantly different

(P>0.05). O.C and T.N is higher at location D, it was significantly different (P>0.05) for O.C at location D while the relationship was not significant for T.N at 0.05 level of probability. The LSD of Ca, Mg and K indicated significant difference at P>0.05 with location. Na and E.A is not significant at 0.05 level of probability. ECEC is higher at location E, it was significantly different (P>0.05). The relationship of B.S and Cu with location was not significant at 0.05 level of probability. The relationship of Fe, Mn and Zn with location was significantly different (P>0.05). Treatment with depth showed that pH and O.C value was highest at depth 0 – 15 cm, there was significant difference(P>0.05). The relationship of T.N with depth was not significant at 0.05 level of probability. The relationship of available phosphorus with depth indicates significant difference(P>0.05). The relationship of exchangeable cations (Ca, Mg, K and Na) with depth was not significant at 0.05 level of probability. E.A and B.S with depth was not significant at 0.05 level of probability. ECEC value at depth 30 - 45 was the highest, LSD indicates significant difference (P>0.05). Micro-elements (Cu, Fe, Mn and Zn) was significantly different with depth (P>0.05).

Table 4.10 reveals the relationship of some selected chemical properties of soils of the study area with nature of soil and location. The pH, O.C and available phosphorus value was highest in flooded soils and location D, it was significantly different (P>0.05). ECEC had the lowest value in the non-flooded soils at location I, it

TABLE 4.10: INTERACTIVE EFFECTS OF NATURE OF SOIL AND LOCATION ON CHEMICAL CHARACTERISTICS OF SOILS OF THE STUDY AREA

Nature of Soil	Location	pH	O.C	Avail. P	ECEC	Cu	Fe	Mn	Zn
			(1:1 H_2O)	(g kg^{-1})	(mg kg^{-1})	(Cmol Kg^{-1})			(mg kg^{-1})
Flooded Soils	D (N6°32'33.6'' E5°37'21.0'')	6.57a	2.31a	0.97a	3.08c	0.68c	38.83e	2.69a	12.73d
	E (N6°32'41.4'' E5°37'22.2'')	6.08c	1.80b	0.61bc	3.84a	0.86b	47.31d	2.63a	14.30b
	F (N6°32'49.1'' E5°37'21.8'')	6.30b	1.69c	0.47c	3.21c	0.87b	66.83a	2.17c	14.24b
Non – Flooded Soils	G (N6°32'32.1'' E5°37'18.9'')	6.07c	1.66c	0.55bc	3.37b	1.09a	51.03c	2.51b	12.50d
	H (N6°32'41.4'' E5°37'12.6'')	6.02c	1.77bc	0.17b	3.70ab	0.83b	55.70b	2.02d	14.80a
	I (N6°32'30.8'' E5°37' 17.7'')	6.27b	1.60b	0.60bc	2.85d	0.84b	36.61f	2.10d	13.82c
LSD (0.05)		0.114	0.094	0.216	0.145	0.119	0.805	0.111	0.191

D: Depth L: Location NS: Nature of Soil ns: Not significant at 0.05 level of probability.
P >0.05 = significantly different
P < 0.05 = Not significantly different
Means followed by common letters are not significantly different

TABLE 4.11: INTERACTIVE EFFECT OF NATURE OF SOIL AND DEPTH ON SOME CHEMICAL CHARACTERISTICS OF SOILS OF THE STUDY AREA

Nature of Soil	Depth (cm)	pH	Organic C	ECEC	Cu	Fe	Mn	Zn
		(1:1 H_2O)	(g kg^{-1})	(Cmol kg^{-1})	(mg kg^{-1})			
Flooded Soils	0 – 15	6.40a	2.13a	3.13c	0.79b	47.21c	2.70a	13.53c
	15 – 30	6.40a	1.77c	3.49b	0.80b	51.27b	2.63a	13.34cd
	30 – 45	6.14c	1.90b	3.34c	0.83b	54.50a	2.17c	14.40a
Non – Flooded Soils	0 – 15	6.34b	1.93b	3.32c	0.18c	41.73d	2.51b	13.83b
	15 – 30	6.00d	1.43e	2.94d	1.10a	47.13c	2.02d	13.17d
	30 – 45	6.01d	1.66d	3.66a	0.97a	54.48a	2.10cd	14.12a
LSD (0.05)		0.114	0.094	0.145	0.119	0.805	0.111	0.191

D: Depth L: Location NS: Nature of Soil ns: Not significant at 0.05 level of probability.
P >0.05 = significantly different
P < 0.05 = Not significantly different
Means followed by common letters are not significantly different

was significantly different (P>0.05). There was also significant difference (P>0.05) between the micro-elements (Cu, Fe, Mn and Zn) with nature of soil and location. The interactive nature of soil and depth on some selected chemical properties of soils of the study area in **Table 4.11** shows pH value of flooded soils at depths 0 – 15and 15 – 30 cm was the highest but this was the opposite in the non-flooded soils of the depths 15 – 30 and 30 – 45, it was significantly different(P>0.05). Value for organic carbon was highest in the flooded soil at depth 0 – 15 while the value for ECEC was high in the non-flooded soil at depth30 – 45 cm, they were significantly different (P>0.05). The values for Cu, Fe, and Zn was high in both the flooded and non-flooded soils, it was Mn that was high only in the non-flooded soils, it was significantly different (P>0.05).

Table 4.12 reveals the relationship of location and depth on some selected properties of soil of the study area. Both pH and organic carbon value was high in location D at depth 0 – 15 cm, there was significant difference (P>0.05). Value for Available phosphorus was high in location E at depth 15 – 30 cm and there was significant difference (P>0.05). ECEC and Fe value was high at location E, depth 0 – 15 cm and 30 – 45 respectively, Mn value was high at location D depth 0 – 15 cm, Zn was high both locations E and F at the same depths of 30 – 45 cm and there was significant difference (P>0.05). The interactive effect of nature of soil, location and depth on some chemical properties is shown in **Table 4.13**. The value for pH and O.C was highest in the flooded

TABLE 4.12: INTERACTIVE EFFECT OF LOCATION AND DEPTH ON SOME CHEMICAL CHARACTERISTICS OF SOILS OF THE STUDY AREA

Location	Depth (cm)	pH (1:1 H2O)	Organic C (g kg-1)	Avail. P (mg kg-1)	ECEC (Cmol kg-1)	Fe (mg kg-1)	Mn	Zn
D(N6°32’33.6’’) (E5°37’21.0’’)	0 – 15	6.60a	2.33a	0.51b	2.79e	45.10g	2.75a	13.50d
	15 – 30	6.20c	1.75c	0.49bc	3.17d	42.35h	2.30c	11.45g
	30 – 45	6.15c	1.86c	0.53b	3.74b	47.35f	2.30c	12.90f
E (N6°32’41.4’’) (E5°37’22.2’’)	0 – 15	6.10c	2.00b	0.58ab	4.07a	38.42i	2.55b	14.25b
	15 – 30	6.10c	1.60d	0.66a	3.48c	54.55b	2.58b	14.35b
	30 – 45	5.95d	1.75c	0.54b	3.75b	61.55a	2.15d	15.05a
F (N6°32’49.1”) (E5°37’21.8’’)	0 – 15	6.42b	1.77cd	0.62ab	3.08d	49.90e	2.50b	13.30e
	15 – 30	6.30bc	1.45e	0.48bc	2.99d	50.70d	2.10d	13.97c
	30 – 45	6.13c	1.72c	0.47bc	3.02d	54.57c	1.95e	14.83a
LSD (0.05)		0.140	0.114	0.108	0.178	0.986	0.136	0.234

D: Depth L: Location NS: Nature of Soil ns: Not significant at 0.05 level of probability.
P >0.05 = significantly different
P < 0.05 = Not significantly different
Means followed by common letters are not significantly different

TABLE 4.13: INTERACTIVE EFFECTS OF NATURE OF SOIL, LOCATION AND DEPTH ON SOME CHEMICAL CHARACTERISTICS OF SOILS OF THE STUDY AREA

Nature of Soil	Location	Depth (cm)	pH (1:1 H_2O)	Organic C ($g\ kg^{-1}$)	Avail.P ($mg\ kg^{-1}$)	Exch. Na ($Cmol\ kg^{-1}$)	ECEC	Fe ($mg\ kg^{-1}$)	Mn	Zn
Flooded Soil	D_1 N6°32’33.6’’ E5°37’21.0”	0 – 15	6.60a	2.90a	0.49b	0.17bc	2.90de	35.80j	2.87a	12.20f
	D_2	15 – 30	6.60a	1.90c	0.49b	0.17bc	2.83e	36.10j	2.80ab	12.40f
	D_3	30 – 45	6.50ab	2.13b	0.51b	0.24b	3.52c	44.60g	2.60b	13.60e
	E_1 N6°32’41.4’’ E5°37’22.2’’	0 – 15	6.20c	1.90c	0.59ab	0.24b	3.52c	36.53i	2.40c	14.00d
	E_2	15 – 30	6.20c	1.80cd	0.64ab	0.25b	4.59a	54.90d	2.40c	13.80d
	E_3	30 – 45	5.83de	1.70d	0.68a	0.19b	3.40c	50.50e	1.50cd	15.10a
	F_1 N6°32’49.1” E5°37’21.8’’	0 – 15	6.40b	1.60de	0.55ab	0.22b	3.50c	69.30b	2.80ab	14.40c
	F_2	15 – 30	6.40b	1.60de	0.52b	0.17bc	3.04d	62.80c	2.70ab	13.83d
	F_3	30 – 45	6.10cd	1.87cd	0.45b	0.22b	3.09d	68.40b	2.40c	14.50c
Non – Flooded Soil										
	G_1 N6°32’32.1’’	0 – 15	6.60a	1.77cd	0.53ab	0.20b	2.67f	54.40d	2.63b	14.80bc

	E5°37'18.9"									
G_2		15 – 30	5.80e	1.60de	0.49b	0.22b	3.50c	48.60f	1.80f	10.50g
G_3		30 – 45	5.80e	1.60de	0.55ab	0.21b	3.95b	50.10e	2.00e	12.20f
H_1	N6°32'41.4''	0 – 15	6.00d	2.10b	0.57ab	0.30ab	4.63a	40.30h	2.70ab	14.50c
	E5°37'12.6''									
H_2		15 – 30	6.00d	1.40f	0.67a	0.18bc	2.37g	54.20d	2.77ab	14.90ab
H_3		30 – 45	6.07cd	1.80cd	0.39b	0.27ab	4.10b	72.60a	2.80ab	15.00ab
I_1	N6°32'30.8''	0 – 15	6.43ab	1.93cd	0.68a	0.19b	2.67f	30.50k	2.20d	12.20f
	E5°37' 17.7"									
I_2		15 – 30	6.20c	1.30f	0.44b	0.37a	2.95de	38.60i	1.50g	14.10d
I_3		30 – 45	0.17cd	1.57de	0.48b	0.19b	2.94de	40.73h	1.50g	15.17a
LSD (0.05)			0.198	0.162	0.153	0.110	0.252	1.394	0.192	0.331

D: Depth L: Location NS: Nature of Soil ns: Not significant at 0.05 level of probability.

P >0.05 = significantly different

P < 0.05 = Not significantly different

Means followed by common letters are not significantly different

soil at location D_1 at depths of 0 – 15 cm. Value of available phosphorus was high in Locations E_3 of the flooded soil at depth 30 – 45 cm, H_2 and I_1 of the non-flooded soils at depths 15 – 30 and 0 – 15 cm respectively. Na value was highest in the non-flooded soil of location I_2, depths of 0 – 15 and 30 – 45 cm respectively. The value of Fe was high in the non-flooded soil at location H_3 with depth of 30 – 45 cm. There was significant difference between location and depth and some chemical characteristics of soils of the study area ($P>0.05$).

4.5 Soil Biological Characteristics

Table 4.14 shows the microbial population of heterotrophic bacteria and fungi respectively. The soil samples D_1 to I_3 had higher heterotrophic bacteria count than Fungi. D_1 had the highest bacteria count with a value of 1.54×10^6 while I_2 the lowest microbial count with the value of 4.8×10^5. G_2 had the highest fungi population of 8.0×10^4 while H_2 and I_2 had the lowest fungi count of 5.0×10^3. Bosah and Omurusi (2007) reported that the high level of microbial population could be due to high organic matter content.

Soil biological activities are controlled by plant residue and SOM quantity and quality and adequate levels of oxygen. Combinations of these factors will result in maximum activities of the soil microbes. Although some organisms have adapted to extreme environmental conditions, overall activity generally diminishes when conditions fall outside of these ideal ranges. For example, the soils of the flooded area become too

TABLE 4.14: MICROBIAL ANALYSIS

SOIL SAMPLES	THBC ($X10^4$cfu/g)	THFC ($X10^3$cfu/g)
D_1	$1.54X10^6$	$3.10x10^4$
D_2	$1.30X10^6$	$2.40X10^4$
D_3	$1.38X10^6$	$2.10X10^4$
E_1	$1.40X10^6$	$2.60X10^4$
E_2	$1.24X10^6$	$1.90X10^4$
E_3	$1.18X10^6$	$1.60X10^4$
F_1	$1.12X10^6$	$1.10X10^4$
F_2	$1.06X10^6$	$9.00X10^3$
F_3	$1.05X10^6$	$7.00X10^3$
G_1	$1.25X10^6$	$1.20X10^4$
G_2	$1.02X10^6$	$8.00X10^4$
G_3	$9.80X10^5$	$6.00X10^3$
H_1	$1.40x10^6$	$2.40x10^4$
H_2	$6.40x10^5$	$5.00x10^3$
H_3	$7.60x10^5$	$8.00x10^3$
I_1	$1.30x10^6$	$1.20x10^4$
I_2	$4.80x10^5$	$5.00x10^3$
I_3	$8.70x10^5$	$7.00x10^3$

Determination of total heterotrophic bacteria and fungi counts (Df = 10^4 and 10^3 for bacteria and fungi: THBC and THFC) respectively.

wet and oxygen diffusion is hindered and overall activity slows down since oxygen is needed by most organisms. Conservation practices of the area such as crop rotation, fertilizer application, weeding, and tillage can affect soil organism activity through changes in aeration and structure, cropping systems, and inputs. These activities were also observed by Vigil and Sparks (2003). However, fungal biomass has been shown to increase in conservation tillage systems as observed in the study area. Earthworm populations tend to be moderate in the areas and they reduce soil disturbances thereby less disruption of fungal hyphae network.

Soil physical, chemical and biological characteristics affect many processes in the soil that makes it suitable for agricultural practices and other purposes. Texture, structure, and porosity influence the movement and retention of water, air and solutes in the soil, which ensuingly affect plant growth and organism activity. Most soil chemical characteristics are associated with the colloid fraction and affect nutrient availability and biota growing conditions. Biological characteristics in soil contribute to soil aggregation, structure and porosity, as well as SOM decomposition and mineralization. Since many soil characteristics are interrelated with one another, it is cumbersome to draw distinct lines of division where one type of property dominates the behavior of the soil. Therefore, understanding and recognizing soil characteristics and their connections with one another is key for making sound decisions regarding soil use and management.

4.6. Soil Resistance and Resilience

The capability of the soil to function may not be measured directly but through indications of the functions especially in the flooded area. Many published works, for example, Seybold, Herrick and Bredja (1999) attempted to quantify the concept of soil resilience but none provided an independent estimate. Soil resilience has been defined as the capacity of the soil to recover its functional and structural integrity after disturbance (Lal, 1993).

The soil is mostly sandy loam which makes the area have greater rate of interrill erosion as a result of rain drop impacts. Such a soil is prone to erosion and soil wash. Seybold *et al.,* (1999) opined that vegetation affects soil resilience. The flooded area haveshort oil palm trees with scattered weeds suchas *Centrosema pubescens, Panicum maximum or Megathyrsus maximus, Plumeria spp*, and these weeds may not be enough to prevent the impact of rain drops. Hence, splash losses. This low amount of vegetation affects soil resilience in the area. This aligns with the findings of Castillo, Martinez-Mena and Albaladejo (1997).

Another factor affecting soil resilience and resistance in the study area is climate. Climatic factors which are considered here are precipitation and temperature. The amount of precipitation of the area is over 2,600 mm with a maximum temperature of 33^{o}C. The soils may be heated. As a result of these, the soils in both the flooded and non-flooded area will be vulnerable to rill and even sheet erosion consequent upon rainy days.

There were few soil fauna, but a lot of micro-organisms as observed by the microbial count (**Table 4.14**). An example of the soil microbes to make the soil recover its function is by degrading the soil contaminants and as Brady (2002) reported, the important indicator of their energy fluxes and changes is nutrient availability. It seems that these microbes will stabilize the soil but the scarcity of plants might negate this. This is especially true for the soil compaction. The soil bulk density that ranges from 1.38 to 1.61, may not pose a threat over time to the recovery of the soil under any pressure. The compaction of the soil did not subject the soil to fragility. However, the area is not much disturbed in large scale especially by farm machinery and trampling. Soil recovery processes is similar to soil forming processes that occur simultaneously and each may affect one or more functions as corroborated by Buol *et al.*(1996).

4.7 Soil Fertility Index (S.F.I) and Soil Evaluating Factor (S.E.F)

Table 4.15 shows the SFI and SEF values of flooded and non-flooded soils. Values of soil fertility index and evaluation factor when calculated can be used to quantify soil fertility (Orobator, 2019). It is observed that SFI was greater in flooded soils (11.77 – 13.35) than in the non-flooded soils (11.49 – 12.40). The same applies to SEF. This agrees with the report of Panwar. The higher fertility in surface soil may be

TABLE 4.15: SOIL FERTILITY INDEX (SFI) AND SOIL EVALUATION FACTOR (SEF)

Soil Sample	Depth (cm)	SFI	Mean	SEF	Mean
		FLOODED SOILS			
D_1	0 – 15	14.10		15.02	
D_2	15 – 30	12.56	13.35	11.60	13.45
D_3	30 – 45	13.39		13.73	
E_1	0 – 15	12.72		10.69	
E_2	15 – 30	15.35	13.30	14.91	12.51
E_3	30 – 45	11.84		11.94	
F_1	0 – 15	12.22		10.31	
F_2	15 – 30	11.15	11.77	9.46	10.44
F_3	30 – 45	11.95		11.54	
		NON-FLOODED SOILS			
G_1	0 – 15	11.82		10.33	
G_2	15 – 30	11.59	11.49	11.66	10.85
G_3	30 – 45	11.06		10.56	
H_1	0 – 15	13.96		16.65	
H_2	15 – 30	10.45	12.40	8.89	13.09
H_3	30 – 45	12.80		13.72	
I_1	0 – 15	12.11		11.26	
I_2	15 – 30	11.07	11.55	9.54	10.46
I_3	30 – 45	11.47		10.58	

SEF = Soil Evaluating Factor **SFI = Soil Fertility Index**

attributed to the accumulation of leaf fall and high microbial activities. Ugwa *et al.,* (2016) and Orobator (2017) opined that soil nutrients are higher in the surface soils due to the decomposition of organic matter. There was generally decrease in soil fertility index with increase in soil depth. Both in the oil palm plantation (non-flooded area) and the pluvial flooded area have much of their concentration of plant roots within surface layers (0 – 15 cm). It seems however that in non-flooded area, the soil evaluating factor (SEF) has no general pattern of decrease with depth; it has its highest values in the surface soils. This finding does not agree with the works of Orobator (2019) who observed that the values of SEF decrease with soil depth in all the land uses he had investigated.

CHAPTER FIVE

SUMMARY OF FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

5.0 Introduction

This chapter summarizes the findings which were drawn from the analyses and discussion of results. This is followed by conclusions and recommendation made for opportunities of further research.

5.1 Summary of Findings

Soil morphological and physico – chemical characteristics vary from one place to another. This may be due to the nature of the soil (flooded and non-flooded) and other factors such as location and depth. The following summarizes the research findings:

1. The nutrient profile levels are similar to those for Benin ecological zone.
2. Pluvial flooding had no detrimental effect on soil quality under oil palm plantation. This is evident in the level of soil organic matter as indicated by the soil colour and also the microbial population as indicated by the microbial count.
3. Sand contents were high on the top soil (0 – 15 cm) of both the flooded and non-flooded area.
4. For bulk density, it has its highest values in the flooded area than the non-flooded area. In the non-flooded area the bulk density is significantly decreased with

depth while in the non-flooded area, it seemed to have no definite pattern. This means the soils have become highly resistant to flooding.

5. The research revealed that porosity and water holding capacity in the flooded and non – flooded soils were significantly different ($P > 0.05$).
6. The differences in the fertility of soils in the flooded and non-flooded areas are fundamentally in their locational characteristics or ecosystem.
7. The research also revealed that the soil pH concentration of the flooded and non – flooded soils was significantly different ($P>0.05$) and it was within the moderate range for establishing oil palm plantation.
8. Exchangeable cations (Na, Mg, Ca and K) showed no significant variation in nature of soils (flooded and non – flooded), location and depth.
9. The relationship of micronutrients (Fe, Zn, Cu and Mn) concentrations was significantly different with the nature of soil, depth and location.

Based on the research findings, the null hypothesis earlier stated is rejected.

5.2 Conclusion

This study shows the characteristics and effects of pluvial flooding on soil quality under oil palm plantation. In various natural systems, floods play a vital role in maintaining key ecosystem functions and biodiversity.

Pluvial Flooding in agricultural areas such as the study area can lead to crop losses through rainfall and erosion, soggy soils and cunctations in harvesting which are further intensified by transport problems due to flooded roads and damaged infrastructure.

5.3 Recommendation

In Nigeria, farmers lag far behind in the use of fertilizers. Higher yields can only be achieved through the careful and judicious use of proper fertilizers. These fertilizers should be sold and apportioned at a fair cost and packaged in quantities suitable for use. Accessibility to manure enhances the organic matter of the soil, which restricts soil erosion and also alternating deep-rooted and shallow-rooted crops improves the soil structure and diminishes erosion at the same time. Soil and water erosion constitutes serious threat to the productive capacity of agriculture. Agricultural resource planners and scientists must better familiarize themselves with labour requirement and capital expense of soil conservation practices. Notwithstanding, the science of sustainable land management has been gaining support, the socio-economic context often makes implementation challenging. Sustainable land practices need to be financially viable for farmers. Government and banks must assist farmers get access to credit and support in implementing erosion thwarting. Another way of managing and subduing soil erosion is to rehabilitate already-damaged land, stop further degradation and put erosion-preventive measures at the core of land management policy. This way, we can help forestay starvation and mitigate climate crisis.

An effective storm water management system and expanses of green infrastructure to incorporate water are mitigation strategies to subdue pluvial flooding. Keeping extant storm water infrastructure free of debris will also help forestay pluvial flooding. Businesses and homes should also be covered by flood insurance.

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