EFFECTS OF DEFORESTATION ON SOIL FERTILITY IN DELTA STATE. NIGERRIA

BY

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DELTA STATE UNIVERSITY, ABRAKA.

JULY, 2014

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DEPARTMENT OF GEOGRAPHY AND REGIONAL PLANNING.
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JULY. 2014

CERTIFICATION

We certify that this work was carried out by Ugboma, Paul Peters in the Department of Geography and Regional Planning.

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Dr. S.I. Efe
Supervisor

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Date

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Dr. C N. Egbuchua
Supervisor

____

Date

DEDICATION

This Thesis is Dedicated to

GOD ALMIGHTY

AND

To The Memory of my Mother

Chief (Mrs.) M.E. Ugboma

DECLARATION

I declare that this is an original research work carried out by me in the Department of Geography and Regional Planning.

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UGBOMA, PAUL PETERS

STUDENT

DATE: ____________________________

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ABSTRACT

This study examined the effects of deforestation on soil fertility in Delta State, Nigeria. In achieving this aim, the data upon which this work premised were analysed in order to compare vegetation physiognomy of deforested and forested areas, examine the effects of deforestation on soil fertility, access the implications of observed soil properties on the yield of yam and cassava in Delta State, determine the most effective soil management method adopted by the farmers and suggest possible ways of soil improvement under deforested plots. An experimental research design was adopted in collecting data from the study area. In doing this, the stratified and simple random sampling techniques were used in sample selection. The study area was stratified into three zones, and four study locations were selected from each zone. Twenty four equidistance plots, twelve each from deforested and forested areas were marked out at 60m x 60m apart, from which soil soil samples were collected for a period of one year. The plots were further divided into quadrants of 1m x 1m to facilitate data collection. Fourty- eight soil samples were collected in each study locations, making a total of 576 soil samples collected for the study. The soil samples collected were taken to the laboratory for analysis. Vegetation physiognomy of tree height was determined by using abney level, tree diameter was ascertained by measuring their girths at breast height using a girthing tape, and all tree population of > 10m tall was identified by species enumeration and was recorded. One thousand two hundred questionnaires were administered on respondents to ascertain the perceive causes of deforestation in the area. The yield of crops (yam and cassava) from different soil management methods were measured from harvested farms, and weighed in kilogram per plot (20m x 20m) and was expressed in tons per hectare. The paired t-test, multiple regression and analysis of variance (Anova) were used in the analysis. Results revealed a variation in the area of tree species loss between forested and deforested areas in Delta State. A similar variation exists in physico-chemical properties of soils of forested and deforested areas in Delta State. Crops yield (yam and cassava) in Delta State depends on soil fertility for their productivity. The result from the mean yield of yam and cassava under different soil management methods, revealed that fallow method have the highest yield followed by soil amendment, slash and burn and tillage methods respectively.The study recommends soil management techniques such as modernized farming, application of mulching, application of lime and crop rotation system of farming should be introduced to improve soil fertility, and enhance agricultural productivity in the area. Intensification of sivilcultural activities should be encouraged.

CHAPTER ONE
INTRODUCTION

1.1 Background to the Study

Tropical rain forest is one of the most valuable ecosystem in the world, which forms a veritable base from which substantial proportion of the populace derive their source of livelihood (Fuwape, 2004). Apart from timber resources, the tropical rain forest is also very rich in variety of other plant and animal products that provide food, energy, medicine, shelter and recreational facilities for people in the region. The forest plays important roles in the amelioration of weather conditions and patterns, protection of soil and food crops (Akinbode, 2002). However, these valuable goods, services and benefits provided by the tropical forest are threatened by deforestation.

Areola (1991) described deforestation as a resource process that involves the extraction of wood from the forest for timber, firewood and the making of charcoal, while (Alegre; Carsel: and Makarim 2004) defined deforestation as human activity that involves the exploitation of trees for either economic or domestic source of power for cooking, Fuwape (2004) defined deforestation as a process that involves cutting down and removal of forest trees and other vegetative cover without replacing them. It results in permanent destruction of indigenous forests and woodlands, and constitutes one of the most critical environmental problems facing the world today.

Soil is a major component of the environmental system, it has been described as the basis of human civilization (Ahan, 1978 and Vine, 2003). Soil occupies a unique position in the ecosystem being at the interface or zone of interaction between the major spheres that constitutes the foundation of the universe, that is, the atmosphere, the lithosphere and the hydrosphere (Areola, 1990).

Aduayi (1985) defines soil as the unconsolidated mineral matter on the surface of the earth that has been subjected to, and influenced by environmental factors such as rocks, climate, vegetation and topography, all acting over a period of time and producing a product (soil) that differs from the material from which it is derived. Soil is the medium for plant growth and for many of the processes that constitute man's life support system; including energy flow and cycling of matter (Areola, 1990).

The physical and chemical characteristics of the soil determine essential qualities of land. The soil also is the repository of much of our waste products both from the home and the work place. Its ability to break down or purify these waste products and re-synthesize new product from them, is one of the most important life-sustaining functions of the soil in the earth environmental system (Areola, 1990).

The role of soil as a medium for food production cannot be over-stressed. It is in recognition of this that Areola (1990) asserted that "no nation can be stronger than his agriculture". But agricultural development depends more than anything else, on the ability of a nation to conserve and exploit fully the potential productivity of its soils. Thus, soils management is based not only on soil agricultural productivity but equally importantly on these other critical roles that it plays in man's total environment. Therefore, proper soil management is imperative in order to eliminate or at least minimize the loss of soil fertility on which all forms of life intricately depend. The need to improve and sustain soil productivity at reasonably high levels necessitates a well planned soil conservation scheme whose primary objective is the prevention of the deterioration of man's biological environment (Akinbode, 2002). Soils in its natural state and under the protective cover of natural vegetation, is described to be in a fertile condition. But, as man begins to make use of soil, its structural and functional balance is disrupted and its productivity may decline with time. This is because the fertility of the soil is easily exploited and its structural stability destroyed by human activities. However, since the soil is a maintainable resource with a natural ability to rebuild its structure and recoup lost fertility, its productivity can often be sustained with proper management practices (Areola, 1990).

Deforestation which is the outcome of depletive human activities through their interaction with natural environment is a major concern to food security agenda of any nation. It undermines the productive capacity of an ecosystem through lost of organic carbon, soil depletion through nutrient loss and soil erosion. It affects global warming through interaction in water and energy balances and results in disruption in circle of carbon (C), nitrogen (N), sulphur (S) and other elements (Oya; Tokashik and Shimo 1995). The increasing trend of deforestation for many agricultural and non-agricultural activities with total disregard of its consequences on soil fertility and the environment and the need to conserve our eco-biodiversity, becomes an issue of concern. This study is therefore aimed at evaluating the effects of these anthropogenic activities on soil fertility and crop production in Delta State. This study will give an insight on how to effect a viable soil management of the rainforest ecosystem in Delta State.

1.2 Statement of Problem

The characteristics of soil and forest cover have been greatly altered owing to different human activities in the form of food crop cultivation, bush firing, road construction, sand excavation, lumbering, fuel wood exploitation, and so on. Several studies have examined different human activities in line with deforestation and the resultant impact on soil (Wunder, 2000; Peters, 2001 and Williams, 2003). Aweto (1998), observed that changes take place in organic matter and nutrient contents of forest top soils when they are cleared, and the organic content of the soil undergoes rapid decomposition and oxidation, and the soil water regime is also altered. Studies by Aborishade and Aweto (1990) and Isichei and Muoghalu (1992), revealed that tree cover undoubtedly influences the soil physical and chemical properties. While changes in soil characteristics usually set in once there is loss of bio-diversity following the conversion of natural forest into different use (Ekanade, 2007). The conversion of natural forest into mono-cultural plantation of tree species destabilizes the soil characteristics. This according to Aweto and Ekiugbo (1994), (Maclean; Litsinger; Moody; Watso and Libetaria 2003), result in decline of the soil chemical properties.

In Delta State, forest resources are undergoing depletion as a result of active deforestation for food crop cultivation, establishment of commercial tree plantations, lumbering, sand excavation, road construction and fuel wood exploitation in the area. Moreso, pressure on the land due to high population density, occasioned by influx of people to the area, the practice of shifting cultivation and annual bush burning all combine to degrade the forest and these have impacted negatively on the forest ecosystem (Peters, 2001). Once the forest is exploited of its trees, the farmers move in for food crop cultivation such as cassava, and yam, and as such the soil physical and chemical properties are greatly affected (Areola, 1991). The farmers in Delta State are mainly subsistence farmers, that majorly cultivate agricultural products of yam and cassava in deforested plots in the area, without recourse to proper soil management methods to replenish the soil. Over the years, the yield from agricultural products of yam and cassava has been decreasing, and the low yield has been attributed to a marked fall in the nutrient content of the soil. While to other farmers, environmental forces like rainfall, sunshine and soil erosion, have been responsible for the low yield. This has compelled some farmers to increase the size of their farm plots, while some have abandoned farming since the forested area that is fertile has been depleted through active deforestation and even the few existing forest have been declared as government reserved or sacred/ shrine for traditional puposes (Peters, 2001).

In the light of this problem, the questions that easily agitate our mind is thus: Does deforestation lead to loss in bio-diversity?, does deforestation have effects on soil fertility? And what are the differences in soil characteristics between deforested plots and those of the adjoining natural rainforest?

Against this background, there is the need to assess the effects of deforestation on soil fertility in Delta State, Nigeria, with a view to ameliorating the situation.

1.3 Aim and Objectives of the Study

The aim of the study is to examine the effects of deforestation on the physical and chemical properties of forest soils in Delta State. To achieve this aim, the following specific objectives are spelt out to:

i. compare the vegetation physiognomy of deforested and adjoining natural forested areas in Delta State.
ii. examine the physico-chemical properties of soils in deforested and adjoining natural forested areas in Delta State.
iii. assess the implications of observed soil properties on the yield of yam and cassava in Delta State.
iv. determine the most effective soil management measures adopted by the farmers over the years to enhance soil fertility.
v. to compare the yield of yam and cassava among the three regions in Delta State.
vi. suggest possible ways of soil improvement under deforested plots.

1.4 Hypotheses

In order to accomplish the aim and objectives of this study, the following hypotheses have been formulated as follows:

i. there is no significant variation in the number of tree species present in deforested and forested areas in Delta State.
ii. the soil fertility status is not significantly dependent on deforestation in Delta State.
iii. the yield of yam and cassava in Delta State is not significantly dependent on soil fertility.
iv. the different soil management methods adopted, has no significant improvement on the nutrient status of the soil in Delta State.
v. there is no significant difference in the yield of yam and cassava among the three regions in Delta State.

1.5 Significance of the Study

The study is of immense significance to a wide range of readership for two main reasons. First, the contribution to theoretical formulation will provide the needed information to soil scientists, agro-climatologists, farmers and other land users on the effects of deforestation as one of the major cause of soil fertility depletion and its attendant low yield of crops. Empirically, the study has contributed to the existing body of literature on bio-geographical studies in Nigeria.

1.6 Scope and Delimitation

This study covers the effects of deforestation on soil fertility in Delta State, Nigeria. The research has limited the scope of the study only to soil samples and
data from vegetation physiognomy in Delta State. The study entails the assessment of the extent to which deforestation has affected soil fertility.

Moreso, the study is limited to collection of soil samples, measurement of tree diameter, height and tree species population in the Delta State. The statistical evaluation of the data was based upon numbers of soil samples from deforested and forested area. The conclusion drawn was limited to validity and reliability of the instrument.

1.7 Study Area

1.7.1 Location

Delta State is located in the rain forest zone of Southern Nigeria. It lies between latitudes 6^0 35'N and 6^0 35' N and between longitudes 6^0 50' E and 5^0 00' E. It is bounded by river Niger and Anambra State on the East, Balyelsa State in the South, Edo State in the North and Atlantic Ocean to the West. The state comprises of 25 local government areas which include Aniocha North, Aniocha South, Oshimili North, Oshimili South, Ika North East, Ika South, Ndokwa East, Ndokwa West, Ukwani, Ughelli North, Ughelli South, Ethiope East, Ethiope West, Isoko North, Isoko South, Patani, Uvwie, Okpe, Sapele, Warri North, Warri South, Warri South West, Udu, Burutu and Bomadi (Figures 1 and 2). The increasing rate of construction activities and mineral exploitation has greatly affected the forest zone of the area. The effects of this on the forest environment of the area is great, especially as manifested in unprecedented soil depletion anomalies and doubtful soil fertility quality.

1.7.2 Relief and Drainage

Delta State landscape is predominantly a subdued low-lying deltaic plain interspersed with water logged depressions and swamps. Despite the low relative relief and the seemingly monotonic nature of its terrain, its landscape can be distinguished into five physiographic provinces namely: Coastal barrier island and ridges, mangrove swamps, low deltaic plain, undulating high plains and dissected uplands.

Delta State is drained by five major drainage basin. These include the Ramos-Niger basin, Ase river system, Utor-Anwai river basin, Forcados-Warri river basin and Benin-Ethiope river basin.

1.7.3 Geology and Soil

The study area is part of Niger Delta and it is underlain by sedimentary rocks, consisting mainly of yellow and white sands with pebbles. Clay and sandy clay occur in lenses (Peters, 2001). Three geological formations occur in the area and they lie one below the other. The Benin topmost formation consists of coarse grained sand and gravels. The second, Agbada formation lies below the Benin formation. This consists of sands and shales. The third formation is the Akata formation which occurs below the Agbada formation and consists of shale and clays.

According to the genetic classification scheme, the soils found in Delta State can be broadly classified into three groups, namely hydromorphic and alluvial soils, ferrasols soils and ferruginous tropical soils (Fagbemi, 1985). The hydromorphic and alluvial soils, covers about 80% of the total land area of the State. And the ferrasols soils are deeply weathered red and yellow brown with abundant free iron oxides. While the ferruginous tropical soils are derived mainly from the basement complex and sedimentary rocks. This soil type are deep, well drained with dark reddish sandy clay loam sub-soil. The geology and soils of the area has formed a veritable base for sustainability of the forest ecosystem, that involved human activities leading to deforestation.

1.7.4 Climate

Delta State enjoys a tropical equatorial climate with long wet season of over ten months. However, the duration and intensity of the wet season decrease slightly from the coast to the hinterland in Delta State it decreases to 9-11 months (Efe, 2007). Apart from the wet season, the state also experiences august hiatus (a dry spells) that last 1-2 weeks annually. Dry season is relatively short lived for one or two months with intermitted rainfall in most part of the state. However, areas that borders the Atlantic Ocean enjoys slight dry season towards the end of December through January. The occurrence of these seasons in the region is associated with prevalence of the tropical maritime (MT) or southwesterly monsoon airmass, Tropical Continental (CT) or northeasterly airmass and the movement of the Inter Tropical Discontinuity (Efe, 2007). The total annual rainfall experience in the state is 2000mm and above. However, the seasonal distribution of rainfall in Delta State showed that the months of July had the highest rainfall with 584mm mean monthly rainfall value, while January recorded the lowest mean monthly rainfall value of 34.3mm. This indicates that there is no marked dry season, as the area experience double rainfall maxima during the month of July and September (Efe, 2007).

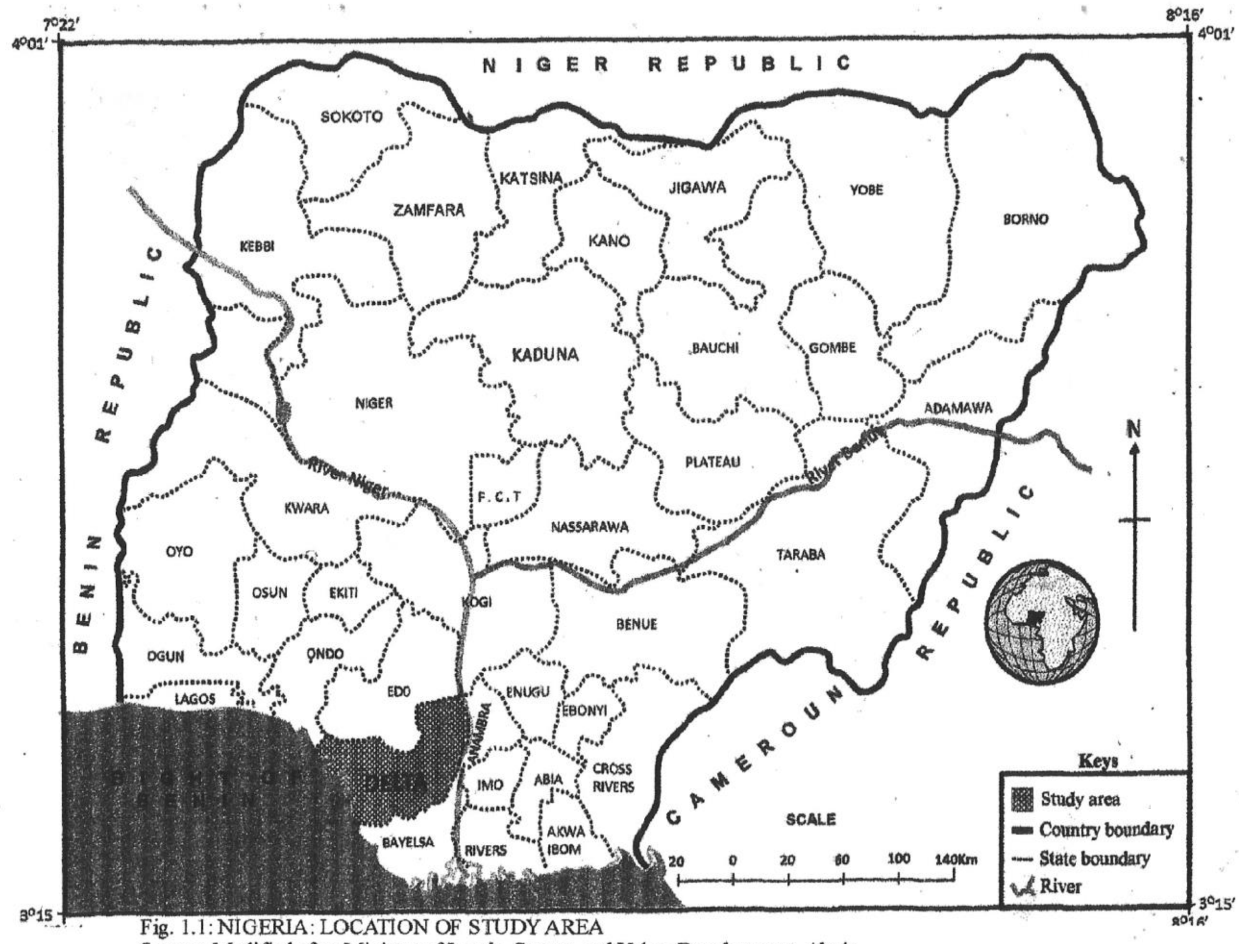


Fig. 1.1: NIGERIA: LOCATION OF STUDY AREA
Source: Modified after Ministry of Lands, Survey and Urban Development, Abuja

The spatial distribution of temperature in Delta State, revealed that Delta State recorded temperature value of between 31^0C and 31.5^0C (Efe, 2007).

Delta State is generally warm, moist and humid throughout the year, with mean relative humidity of 90% in the morning and 55% in the afternoon. This showed that relative humidity decreases gradually from the coast to the north (Efe, 2007).

However, climatic factors of rainfall, temperature and humidity influences the forest environment. The evergreen tree species in the area, attracts human activities of lumbering and fuelwood exploitation leading to deforestation.

1.7.5 **Vegetation**

Delta State is tranversed by a variety of vegetation types. These types ranges from mangrove swamp forest, fresh water swamp forest, tropical lowland rainforest and the grassland.

The mangrove swamp forest thrive in the saline brackish water areas of the state. It is characterized by swampy grounds often separated by narrow bodies of water and creeks. The mangrove swamp forests in Delta State possess the following dominat economic species namely: *Rhizohara racemosa, R. Mangle, R. Harrisonia and Avicennia Africana.* The fresh water swamp forest is situated much more inland than the mangrove vegetation and is free from contact of ocean water, the species which are found within this zone include Raphia Spp., Calamus Spp., *Irvingia gabonensis*, *Termilania Spp*. etc. But the most common among all these is the Raffia Palm (Aweto, 2002). The tropical lowland rainforest occurs inland from the mangroves with a considerable number of tree species, wood climbers, creepers and under growth. The trees of the tropical rainforest are known to characteristically evergreen. While the grassland vegetation occurs in discontinuous patches in some areas of the state. The grassland vegetation in Delta State is unique and different from that of Northern Nigeria. The grassland in Delta State are known to be treeless and dominated by grasses such as *imperata cylidrica, loudeita arundinacea, panicum maximum* and *hyperrhenia spp.* (Aweto, 1987).

The natural vegetation in Delta State, has been seriously disturbed over the years due to deforestation.

1.7.6 Population

With a population of 4,098,391 in 2006 (NPC, 2006), Delta State has a high population density that is concentrated in the core areas of the state. These areas include: Asaba, Akwuku-Igbo, Agbor, Ubulu-Ukwu, Kwale, Obiaruku, Ughelli, Isiokolo, Abraka, Oghara, Oleh, Ozoro, Patani, Effurun, Sapele, Otor-Owhe, Orerokpe, Koko, Warri, Bomadi, Burutu and Udu. In recent time, the area has been experiencing high population density, occasioned by influx of people to the area, for either one economic activity or the other. And this has resulted in undue pressure on the land in the form of various human activities leading to deforestation.

1.7.7 Economic Activities

Farming is the most important occupation in the study area. Food-crops are cultivated under shifting cultivation. Shifting cultivation with bush fallowing is an economy in which farmland are rotated rather than crops. Essentially, in this system a farmer clears a piece of land and farms it for one or two years until fertility is lost. He then moves to another piece of land, leaving the former in fallow for 5 - 7 years (depending on the level of fertility), so as to regain fertility.

In Delta State, crops are almost entirely grown on land freshly cleared from bush. The plots are brushed with cutlass, together with either partial or full felling of the larger trees. This is done between the months of December and early March. The area is then burnt over just before the commencement of the rain. Planting is done between March and April.

The main crops are yam and cassava and they are grown with one to five intercrops. These intercrops include maize, okro, pepper, tomatoes, melon, cowpeas and groundnut.

Usually, cassava is interplanted about July after tuber development stage of yam. Rice cultivation is now in the area and it is cultivated mostly in grassland areas under shifting cultivation. Cassava and yam are produced in commercial quantity and they are sold in local markets and urban centres such as Port Harcourt, Warri, Lagos, Owerri etc.

Human activities in the form of food crop cultivation and tree crop plantations establishment, by both individuals and government agencies, has led to deforestation.

Delta State is an important state in Nigeria, has its capital situated in Asaba. The state comprises many urban areas that has the following function of administrative centres, health centres, commercial centres and educational centres. The socio-economic activities in Delta State are classified into: the primary activities which agricultural activities such as peasant farming and livestock farming for personal consumption in the areas. The secondary activities such are basically the processing activities such as carpentry, tailoring, carving, hair dressing etc, which is the conversion of raw material into finished good which is spread around most of the communities in Delta State.

While in Akwukwu-Igbo, Ubulu-Ukwu, Umunede, Emu-Uno, Okpai, Ughelli, Isiokolo, Abraka, Oghara, Oleh, Ozoro, Patani, Effurun, Sapele, Otor-Owhe, Orerokpe, Koko, Warri, Bomadi, Burutu and Udu, they are basically involved in primary activities such as agricultural activities involving farming, sand excavation, lumbering and fuelwood exploitation, leading to deforestation.

CHAPTER TWO

CONCEPTUAL FRAMEWORK AND LITERATURE REVIEW

2.1 Conceptual Framework

This study adopted the integrated ecosystem based approach, were ecosystem, man and the biosphere, tree influence cycle and soil fertility concepts were examined.

2.1.1 The Ecosystem Concept

The ecology of an area can be considered as a set of objects together with relationship between the objects and their attributes (Bernard, 2004). The view of ecology encouraged by such a framework is obviously one, which stresses interaction between parts and the mechanisms, which control such connectivities and is called a system approach. We can therefore designate a special class of systems, which have ecological components and call them ecosystem.

The term ecosystem was coined in 1935 by Tansley, but the concept has a much longer history, many attempts having been made to characterize the immense complexity and holistic character of the natural world. According to him, the term ecosystem includes not only the organisms, but also the whole complex of physical factors forming what we call the environment.

A more rigorous definition by Bernard (2004) opined that any area of nature that includes living organisms and non-living substances interacting to produce an exchange of materials between the living and non-living parts is an ecological system or ecosystem.

Energy in Ecosystems

The concept of energy flow through the ecosystem is very important. The energy input from the sun controls life and thus everything that makes up natural resources. Energy enters the ecosystem as free solar energy and is converted by green plants into chemical energy in the process known as photosynthesis. Some of this energy is dissipated as heat during plant respiration. What is left is converted into organic matter and forms part of the living weight of plants (Areola, 1991).

The whole process by which solar energy is converted to organic matter is known as biological production. In agriculture, most of man's effort is geared towards increasing the productivity that is, the yield of cultivated crops (Peters, 2001). In doing this, all other elements of the ecosystem are subordinated to crop production. Plants which man does not make use of and which may compete with cultivated crops for the available ecological resources are termed weeds and are removed. In the same way, animals, insects and birds which in any way inhibit the production of the plants or animals favoured by man, are termed pests and are destroyed (Peters, 2001).

The energy fixed by plants and locked up in organic matter is passed through ecosystem by means of food chain. At each trophic level the potential energy in organic matter is broken down and reconstituted for the use of the organism. Some of the energy is again dissipated through respiration. This dissipation of energy at each stage is known as entropy. As a result of entropy, the energy available to man decreases down the food chain (Areola, 1991). Energy flow and food chain in an ecosystem has the symbols of A indicating food by the organisms at the trophic level, F indicating energy lost in the feaces and other excretory products, C indicating energy lost through decay. While R indicates energy lost to respiration (see Fig. 2.1).

To summarize, energy enters the ecosystem as free, solar energy and leaves it as heat, having undergone changes from a concentrated to a dispersed state. Within the ecosystem is found energy – rich organic matter, which upon the death of the organism, either plant, animal or fungus undergoes decomposition (Peters, 2001). The complex organic materials are broken down to relatively simple inorganic compounds, with consequent dispersal of energy (Areola,1991).

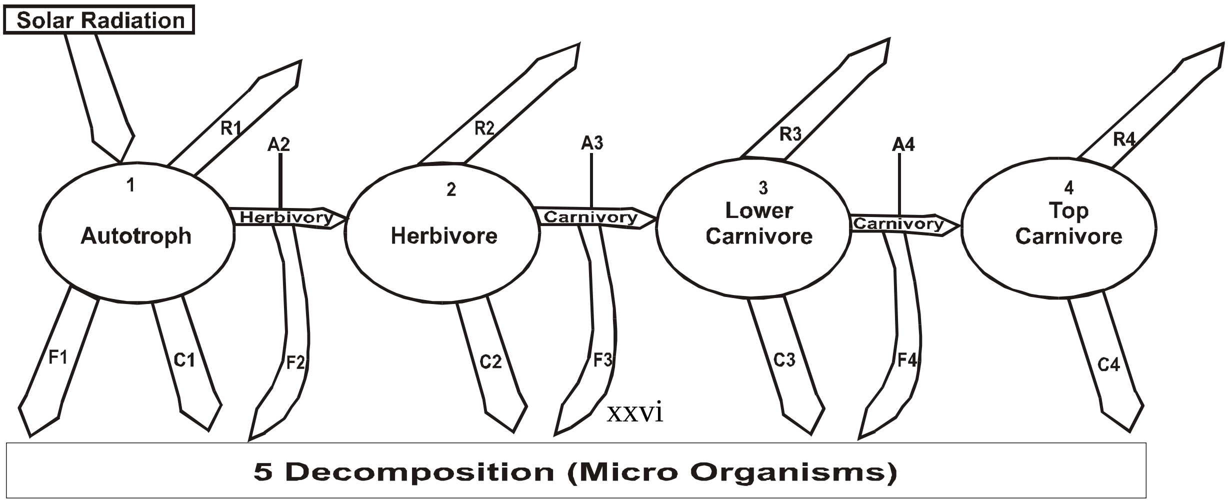


Fig. 2.1: Energy flow and the food chain

(**Source:** Vine, 2003).

Key:

A1 – A4: Food by organism at trophic level.

C1 – C4: Energy lost through decay

F1 – F4 : Energy lost in excreatory products

R1 – R4: Energy lost to respiration

The circulation of nutrient elements within the ecosystem is very important. These include oxygen, carbon and nitrogen and inorganic elements such as calcium, magnesium, potassium, sodium and phosphorus. These circulate between the biosphere and the physical environment (Areola, 1991). Furthermore, some are locked up in such a way that they are not readily accessible for use by living organisms. Modern man increasingly interferes with nature to increase the efficiency of these cycles or to compensate for the short supply of some nutrients by adding artificial fertilizers. The overall result of these actions has been to speed up the natural cycles while introducing larger quantities of materials than they can cope with. The consequence have been noticed in the pollution of the environment, the eutrophication of water bodies and the net loss of mineral elements from the land to the sea through erosion and leaching (Areola, 1991).

Finally, biological functions in the ecosystem, especially biological productivity, have limits dictated mainly by the amount of solar energy received but also by abiotic factors, like climate and mineral nutrients. The concept of limiting factors and especially of the need to resist man's use of natural resources is of paramount importance since the rate of replacement of the renewable resources is itself limited (Areola, 1991).

The ecosystem concept provides important guiding principle for resource management. One of such principle is that the reciprocity between the living and non-living parts of the ecosystem. When man make use of any component of the ecosystem, he may bring about changes in other components (Areola, 1991).

This concept has been used by some scholars in the study of deforestation and soil of the deforested areas, (Neptsad; Vrissimo.; Alenear.; Lima; Nobre; Potter; Moutinho and Brooks 1999) on large-scale impoverishment of Amazonian forests by logging and fire, and on tropical forest resources Peters (2001).

However, this concept has a relationship with this current study, since the study area brings together the environment, man, plants and animals within a single framework, within which there is an interaction among the various components of the ecosystem. Thus, Delta State, which is the study area represents the environment, the population of the area stands for the man, iroko, mahogany as well as grass cutters, entelopes found in the area represents the plants and animals respectively.

2.1.2 Concept of Man and the Biosphere

This concept explains the role of man in changing the attributes of the ecosystem (Spellerberg and Sawyer;1999). The characteristics of soil and forest cover have been greatly altered owing to different human activities. Several studies have examined different human activities in line with deforestation and the resultant impact on soil (Wunder, 2000; Williams; 2003). The cutting down of trees in the forest for timber reduces the population of certain trees of high economic values in the forest. This results in the loss of bio-diversity as well as the floristic composition of plants Williams (2006). The originally contiguous rainforest cover in many places has now reduced to forest islands, surrounded by different land uses such as agriculture and settlements development (Ogunleye; Adeola.and Aduradola 2004). In South-Eastern Nigeria, this zone is represented by the oil palm bush which covers hundreds of square kilometers in Imo and parts of Anambra and Akwa Ibom States.

Owing to centuries of tree felling for agricultural, settlement and constructional activities, deforestation has occupied the original place for plant habitat (Spellerberg and Sawyer, 1999). The resultant impact of this deforestation is seen in the area of soil erosion, reduction in the physical and chemical characteristics of the soil and loss of species diversity (Williams, 2006).

In Nigeria, human activities in the form of agriculture, lumbering, fuel wood exploitation, bush fire, road construction and mining has degraded forest fringes to secondary forest. Areola (1991) noted that once the forest is cleared, the soils tend to dry out progressively and some may develop clay pans and lateritic crusts, as such tree regeneration is made more difficult.

However, this concept has a relationship with this current study, since human activities of agricultural practices, bush fire, lumbering, road construction and fuel wood exploitation in the study area, has led to the changing attributes of the ecosystem.

2.1.3 Concept of Tree Influence Cycle

The concept of tree influence cycle has been applied in bio-geographical studies. The knowledge of the effect of trees on the soil is essential for evaluating what happens to the soil when the plant covers in the rainforest ecosystems are removed, and the desirability or otherwise of retaining tree plants in the forest ecosystems (Dunham, 1991).

Tree cover undoubtedly influences the soil physical and chemical properties (Aborishade and Aweto, 1990; Isichei and Muoghalu, 1992). Changes in soil characteristics usually set in once there is loss of bio-diversity following the conversion of natural forest into different use (Ekanade, 2007).

The conversion of natural forests into monocultural plantation of tree species destabilizes the soil characteristics. This according to Aweto and Ekiugbo (1994), Maclean et al, (2003), result in decline of the soil chemical properties. On other land use such as food crop production, following deforestation, the influence is quite distinct due to rapid deterioration in soil physical status over time (Bernard, 2004).

The trend of a steady decline in the soil characteristics over time suggests that deficiency in soil chemical characteristics will limit the effectiveness of deforested ecosystem. Reforestation by plantation does not function as natural bush fallow vegetation that recycles mineral nutrients to the topsoil (Isichei and Muoghalu, 1992).

The impact of frequent cultivation and burning before cultivation has been reported to reduce the build-up of organic matter and nutrients in the soil Ekanade, (2007). The contribution of tree crowns to organic matter and nutrient accumulation is reduced following the opening up of the natural forest cover (Aweto and Iyanda, 2004; Aweto and Moleele, 2004).

However, this concept has a relationship with the current study, since human activities of extraction of wood from the forest for either economic or domestic purposes, has led to loss of vegetal cover.

2.1.4 Concept of Soil Fertility

A soil type is regarded fertile if it contains all essential factors such as light, temperature, air and mineral nutrient elements in adequate and balanced proportions to support the growth of plants (Youdewei; Ezedinma and Chapa 2010). The concept points to the fact that the soil may contain almost all elements, but deficiency of one element may render it unproductive and for a nutrient element not present in adequate amounts, a certain maximum yield was obtainable by the addition of that nutrient element. This means that all nutrients should be available in the soil in an appropriate and balanced amount in order to promote plant growth. Therefore it is important to continually maintain and sustain the soil by adopting soil management techniques that will help to attain optimal agricultural productivity (Asadu and Nweke, 2001). Our forefathers for long recognised the needs to keep the soil fertile. They cultivated the soil and added manure to improve on the nutrient status. The need to stay much longer on a piece of farmland and maintain its fertility by replenishing the soil with elements that have been removed from the soil through crop uptake and metabolism. Therefore, there is need to add nutrient elements to depleted soils, heralded the birth of series of fertilizer experiments on the response of crops to nitrogen, phosphorus and potassium otherwise known as N.P.K. (Asadu and Nweke, 2001).

Areola (1990), and Angelsen and Kaimowitz (2010) posited that soil in its natural state and under protective cover of natural vegetation, the structural stability of the soil is maintained and, in its functional relations through the flow of energy, gaseous exchange and mineral cycling, it is in a state of dynamic equilibrium with the other components of the ecosystem. But, as soon as man begins to make use of soil, its structural and functional balance is disrupted and its productivity may decline with time. This is because the fertility of the soil is easily exploited and its structural stability destroyed by human activities. However, since the soil is a maintainable resource with a natural ability to rebuild its structure and recoup lost fertility, its productivity can often be sustained with proper management practices. What this means is that as man makes greater demands on the soil resources, he needs to modify and improve upon his soil management techniques. Thus, measures aimed at conserving the soil resources must keep pace with the increasing pressure of population and human activities on the land. Failure to do this is bound to result in declining land productivity and eventual environmental disaster. Thus, land and soil resources deserves closer attention and more prudent management measures in order to continue to reap the fruits and benefits of soil as a resource

From the above conceptual issues discussed, this study adopts the ecosystem concept, since the study is centered on the forest ecosystem. It examined how different interactions that occur in the tropical rain forest ecosystem have created deforestation. All interactions in an ecosystem are not the same; some may leave the ecosystem with positive impact while others may record negative impact. However, the complex interaction between man and the plants in an ecosystem suggest that a more meaningful and realistic approach to the study of deforestation in the tropical rainforest has to be within the framework of the ecosystem concept.

2.2 LITERATURE REVIEW

In this section, the tropical rainforest ecosystem, different soil orders in the rainforest ecosystem, causes of deforestation, trend of deforestation, methodological approaches and problems of deforestation are discussed.

2.2.1 Tropical Rainforest Ecosystem

A broad review of the rainforest environment and ecology is necessary in order to place the impact of man's exploitation in the proper perspective. Tropical rainforest is one of the oldest types of vegetation, and is the climax vegetation in areas with high annual rainfall distribution of over 2032 mm/80 inches, average temperature of about 26^0C with little variation throughout the year, and average humidity of between 60% and 80%. Typical rainforest consists of three tree layers, (see Fig. 2.3). Trees in the uppermost layer can grow to height of about 60metres. In Africa, this type of vegetation is found around the Gulf of Guinea, the West African Countries and in the Congo basin (Neptsad, D.C.; Vrissimo, A.; Alenear, A.; Lima, E.; Nobre, C; Potter, C; Moutinho, S and Brooks, V. 1999)

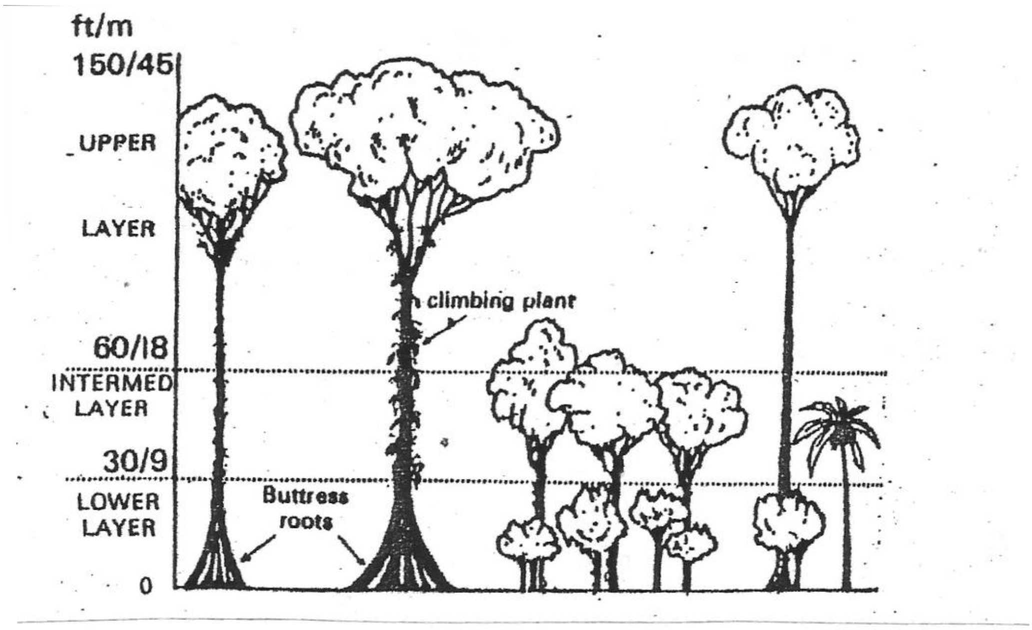


Fig. 2.2: Sketch Showing the three Distinct Layers of Tropical Forest, (Source: Aso, 2001)

In Nigeria, rainforest is confined to the southern part of the country The states include Ogun, Ondo, Ekiti, Delta, Edo, etc.

According to Jules (1998), most trees of the rainforest ecosystem have a monotonous, sombre appearance, which characterized the tropical rainforests. The trees are straight, slender trunk with thin, smooth bark and branches occurring near the top trunk.

The crowns are small, their shape depend on the layer which they belong to. The roots are concentrated in the surface litter and soil layer and extra anchorage is achieved with buttress roots. Leaves are dull, dark green, leathery, and more or less entire. Flowering, fruiting, loss of old leaves and growths of new leaves are continuous throughout the year.

Other characteristics of rainforest according to Areola (1991), are that trees of the three layers differ in both their height and shape. The layers are also grouped into A, B and C stories, (Figure 2.2) "A" storey trees are scattered with wide spreading crowns, "B" storey trees are closely packed with smaller crowns and "C" storey trees are dense, closely packed with their crowns shaped in different ways. Saplings are generally unable to grow near a mature number of the same species, thus the sapling replacing a dead tree is almost invariably a different species. The shrub layer of a tropical rainforest consists of a mixture of true shrubs and saplings which are unable to mature due to lack of light, while the herb layer consists of entirely of shade loving plants (sciophytes). Lianas and epiphytes are scattered throughout the main vegetation layers. They have solved their light requirement problems by climbing over other vegetation (Lianas) or growing on the branches and trunks of trees (epiphytes).

Tropical rainforest is the most species diverse of any vegetation Terborgh, (1992). Plants growing in such habitats receive continuous water and warmth, While a deficiency of nutrients is unlikely to occur due to rapid recycling. The only limiting factor is sunlight, and it only applies to plants of the lower canopies.

Structurally, the rainforest consists of three tree layers, the upper, intermediate and lower layers, (see Fig. 2.3). Many of the emergent species in the forest are important trees. Infact, in the forest, the emergent trees exist for long periods in a state of suppressed growth, under the shade of the canopy, until a gap occurs which allow them to grow up. The gaps are created by the falling down of dead trees (Bernard, 2004). Thus, there is a high rate of mortality among the seedlings of emergent species. In contrast, many of the middle and lower storey trees have shade – tolerant seedlings which grow up under the dense overhead shade of their parents. Generally speaking, competition is intense among the trees in the forest that only a small proportion of the pole-size seedlings under the shade actually grow into trees.

(Ogunleye; Adeola; Ojo and Aduradola 2004) opined that floristically, Nigeria forests are less rich than similar forest in other parts of the humid tropics. Even so, there is a wide variety of species which increase in number from the drier to the wetter parts of the forest region. The drier forests are dominated by tree species belonging to the family sterculiaceae and to a lesser extent by species of the families ulmaceae and moraceae. Examples of the sterculiaceae include *Triplochiton Scleroxylon* (African maple, obeche), *mansonia altissima* (mansonia), *sterculia tragacantha* (African tragacanth, kanaya) etc. Examples of the ulmaceae and moraceae include *Celtis brownii*, C. *Mildbreadii*, C. *millenii*, *C. zenkeri, and Morus mesozygia* (West African mulberry) (Areola, 1991).

Of all terrestrial ecosystems, the tropical rain forest probably exercises the greatest influence on the immediate atmosphere and the underlying soil. It creates its own internal climate, which is most crucial to the sustenance of its diverse life forms and the stability of the whole ecosystem. Much of the negative impact of man on forests results from the modification of this unique internal climate (Areola, 1991).

Factors Influencing the Forest Environment

The factors influencing forest environment include light, temperature, water supply, soils and the nutrient cycles, and biotic factors.

Light:

Different intensities of light and variation in its spectral composition affect plant growth, reproduction and biological production and thus indirectly the structure of the forest. The greatest light intensity is received at the tops of the tallest trees, which are referred to as the emergents. Relative light intensity in crowns with dense foliage may be only 24% of full light. At the closed canopy of the middle and lower tree layers the relative light intensity drops to about 3% of full light. This zone is characterized by intense competition for light among plants. The forest floor is the dim layer where relative light intensities of less than one percent have frequently been recorded. Light intensity, especially at the forest floor, changes with the angle of incidence of the sunrays. It also changes with the seasonal variation in atmospheric condition or haziness. Variation in light intensities determines plant distribution on the forest floor. The forest is composed of plants with varying degrees of tolerance to light. The shade provided by the upper tree layers is crucial to the survival of many plants of the undergrowth among seedlings of small size representative of the upper layer trees prevented from growing up by the low light intensity inside the forest (Areola, 1991).

Temperature:

According to Bernard 2004), mean monthly temperature for meteorological stations in the tropical forest zone give the impression of uniformity from month to month. However, these monthly mean temperatures fluctuate. Soil temperature fluctuates less than air temperature both seasonally and diurnally. Furthermore, at or below a depth of about 75cm there may be no diurnal fluctuation at all while the seasonal range is also very small (Hyde, 2010). The maximum soil temperature under a closed forest probably never exceeds 30^0c in contrast to soils in open clearings whose temperature occasionally may exceed 50^0c.

Water Supply:

Although tropical forest are found in high rainfall regions, they thrive best on freely – drained rather than swampy soils. Thus, from the ecological point of view, most tropical forests are mesophytic. Usually, there is variation of soil and plant communities along relief catenas. Soil moisture is a crucial factor in determining such local patterns of vegetation (Areola, 1992).

Rainfall is the chief source of water supply in tropical forests; in Nigeria forest occurs in areas with at least 1143mm annual rainfall; but dew, fog and low clouds are also important sources. Apart from the actual water supply, the relative humidity of the air is an important ecological factor in tropical forest. Moist atmospheric conditions both around and within the forest are crucial to the survival of its varied life forms. However, prolonged saturation of the air is undesirable because it interferes with the process of evaporation. This is an important process which affects the transportation or circulation of mineral elements within the plants (Vine, 2003). Day time relative humidity varies widely from the upper tree layer (70%) to the forest floor (90%). In forest margins affected by seasonal rainfall or the harmattan, day-time relative humidity values may fall, thereby temporarily creating dry weather conditions. For example, relative humidity on the forest floor can drop to about 70% which may be too dry for certain plant species in the undergrowth (Areola, 1991).

Nutrient Cycling:

Nutrient cycling in the forest is restricted largely to the top few centimetres of the soil that is rich in humus. The reason for this can be found in the nature of the forest floor. The soils are predominantly deeply weathered and intensely leached ferralitic soils with low base saturation consist mainly of kaolinite with abundant ion and aluminium oxides; therefore the cation exchange capacity of the soils is very low except for the humus layer at the top. In addition, the reserves of weatherable minerals are low. The soils are acidic in reaction with some having pH values as low as 4.0. The C/N ratio may be as high as 10 (Asadu and Nweke, 2001).

Because of the poor nutrient holding capacity of the soils, the greater proportion of nutrient capital of a mature tropical forest ecosystem is contained in the vegetation particularly in the tree trunks, leaves and twigs. Nutrients are immobilized for long periods in the tree trunks. Soil nutrient is maintained through the supply of litter by vegetation, and through root exudates. The soil nutrients are protected against leaching and erosion by the dense vegetation and root systems which capture the nutrients washed down by drainage water and return them to the top layers of the soil. Indeed, in a mature forest, nutrients are kept more or less in a closed cycle between the vegetation and the top soil (Asadu and Nweke, 2001)

Thus, the tropical forest lives precariously on the products of its own decay, and once a forest area is destroyed, regeneration is very slow. With the removal of the vegetation, the ecosystem loses a great deal of energy and nutrient-rich materials; the nutrient cycle is greatly disturbed and soil humus content falls. The change in microclimatic conditions, especially the drier air and the more intense insolation on the ground surface, will promote faster rates of organic matter decomposition (Areola, 1991 and Stenstrom, 2010).

Biotic Factors:

The tropical forest is characterised by its diversity of life and complex interaction between organisms. The diversity of life is thought to be due to the multiplicity of microhabitats. Areola (1991) has classified the plants into two types: the autotrophic plants which have chlorophyll and the heterotrophic plants which do not. The autotrophs include mechanically dependent plants such as the climbers, stranglers and epiphytes. The heterotrophs consist of saprophytes such as fungi, bacteria and vascular saprophytes; and vascular and non vascular parasites.

Insects are the most numerous and prolific of forest animals. They inhabit particularly the litter layer and the forest canopy. They thus constitute a major link in the nutrient cycles within the forest. Other animals include many tree frogs, tree snakes and lizards, mammals and arboreal birds. Like the plants, there is vertical stratification amongst the animals with particular species feeding, moving and resting at particular layers in the forest. However, the upper tree layers where food is most abundant carry the largest animal population (Adesina, 2006).

2.2.2 Different Soil Order in the Rainforest Ecosystem

The major soil types can be related to the factors of climate, vegetation, lithology and topography.

Climatic factors, particularly rainfall, influence the rate and depth of weathering and pedogenesis. The soil moisture regime, which is very important in agricultural productivity, is highly correlated with the incidence of rainfall (Kunde, 1995).

The density of vegetation cover also conditions soil moisture because it determines the extent to which the soils are protected against intense insolation. The humus content of the soils which is so important in their productivity and structural stability varies with the nature and density of vegetation cover (Okpor, 2008).

Within the broad ecological zones of the rainforest, the distribution of major soil types is largely related to parent material lithology which influences such properties as soil depth, texture and stoniness, moisture conditions, nutrient status and the proportion of weatherable minerals.

According to (USDA, 2004) classification, the major soil groups in the rainforest ecosystem are oxisols, alfisols, utisols and spodosols.

Oxisols:

This reflects an intense weathering under a hot humid climate on an old level, unrejuvinated landscape. Many of the oxisols are shallow and have developed in old eroded soils or have been exposed to become plinthite. Intensive and continuous weathering with losses of silicates by hydrolysis result in accumulation of sesquioxides. The oxisols may have developed through several climatic periods. Oxide clay dominates the clay fraction, and the silicate clays that remain are primarily koalinitic in nature (Badejo et al, 1999).

Horizons of oxisols are separated by gradual transition zones with diffused boundaries. Large quantities of iron and aluminium oxides are present. The CEC of oxisols is generally less than 20 cmo/kg soil. Base saturation is less than 40%. They are very unfertile because they lack weatherable minerals. They are very low in total phosphorus and often show a high phosphorus fixation capacity. Aluminium toxicity at low pH values is the most frequent limiting factor to plant growth in these oxisols (Badejo et al, 1999).

Oxisols are cultivated with tree crops such as rubber, coffee or oil palm. Oxisols respond to proper management technique, which may involve extensive use of fertilizer with particular attention to micro nutrient needs. Heavy rates of lime are required to reduce aluminium toxicity. Shifting agriculture is highly practiced on oxisols (Badejo et al, 1999).

Alfisols

In this type of soil, primary emphasis is placed on the presence of argillic (kandic) horizons with a high base status. The parent materials tend to be crystalline acid rocks, higher in quartz and lower in iron. The resulting soil is higher in texture and because of the absence of iron, is less likely to have plinthite. Also, kaolinite clays dominate with 2:1 clays often present in small amounts. This gives a low CEC, but the base saturation is sufficiently high (>35%) to classify them as Alfisols. Iron concretion may be found in the profile as a result of leaching of free iron. The reserve of weatherable aluminium is often appreciable. The agricultural potential of Alfisols is good. They are moderately low fertility status but respond well to fertilizer. Arable crops are grown in these soils (Badejo et al, 1999).

Utisols

These soils are considered to be in the final stages of weathering and even kaolinite and quartz have been altered. Many are polygenetic and reflect previous as well as present environmental conditions. Generally, most of the bases are in the organic matters of the surface mineral horizon while fertility and percent base saturation decrease with depth. To ensure high productivity, these soils are either heavily fertilized or managed by shifting agricultural methods (Asadu and Nweke, 2001).

Spodosols

These soils are found scattered among the soils, in swampy areas, particularly in areas of high rainfall, and in areas of sub-humid to semi-arid conditions, where local depressions cause water accumulation. The particle size analysis of these soils indicates that sand was dominant, and clay was generally higher than silt. While ECEC, exchangeable Mn, total N and organic matter were critically low (Badejo et al, 1999).

In terms of soil physical properties of the rainforest ecosystem, particle size analysis of the soils indicated that sand was dominant, clay was generally higher than silt with little variation across the soils zone. The relative proportions of textural classes across the zones shows that sandy loam dominates all other textures, followed by loamy sand and sandy clay loam (Asadu and Nweke, 2001).

In terms of chemical properties, the study by Kunde (1995) on the soils of rainforest, revealed that the soils are slightly acidic and contain small amounts of exchangeable aluminium. The high degree of base saturation indicates that the soils are not extensively leaded. Soils under forest fallow contain moderate amounts of Ca, Mg and K in the surface layer. The relatively high amount of total N in most of the surface soils suggest that a substantial amount of the nitrogen may be mineralized during the first cropping season after clearing (Wardle.; Zackrisson and Nilson 2008).

2.2.3 Causes of Deforestation

Areola (1991), noted that in the past, forest lands suffered from traditional agricultural practices, in modern times, they are in danger of being lost through five kinds of human activities:

i. Agricultural Practices.

ii. Bush fire

iii. Road construction and red earth quarrying.

iv Lumbering.

v Fuelwood exploitation

Agricultural Practices

In recent years many people have taken to farming when they retire from service (Areola, 1991). Local farmers are also forming co-operatives in order to engage in large-scale production of certain crops including cassava, maize and rice. To accommodate these newcomers in the rural areas much of the formerly undisturbed or secondary forest re-growths are being cleared. The same easily acquired land is also preferred for government projects, because they can be exploited without displacing the local farmers. In Benin, Ondo and Ijebu-ode, many hectares of former high forests are now occupied by plantations of rubber, cocoa and oil palm owned by government ministries or private citizens. For instance, in the Delta province, rubber dominates the vegetal cover of large areas of the Urhobo plains adjacent lands. Commercial tree plantations have been restricted largely to the forest reserves but local farmers are being encouraged to plant exotic trees along with their tree crops. Furthermore, in some states, in Lagos for example, large areas of secondary forest re-growths are being reserved for the eventual development of commercial tree plantation (Peters, 2001).

Road Construction and Sand Excavation.

Road construction and sand excavation., which are very wasteful of land and forest, have been responsible for much forest clearance in most states of Nigeria. These human activities leads to deforestation of forested land.

Bush fire

A very important factor militating against the maintenance of a semblance of forest vegetation as part of the rural landscape in many parts of Nigeria is the annual bush fire. Crops have often been inadvertently destroyed by fire. Burning destroys the restorative fallow vegetation annually and this probably reduces the rate at which soil fertility is restored during the fallow period (Asadu, 1999).

Forest fire has occurred in different parts of the world, destroying large tracts of both tropical and temperate forests. In 1998 forest fire broke out in many parts of the world, burning an estimated 92,800 square kilometres (Myers, 2000). The wildfires were ranging in Canada, Siberia (80,000 square kilometres burned), Mongolia, Alaska, Florida 916,000 square kilometres burned), Brazil, Mexico, Greece (400 square kilometres burned), Indonesia (24,000 square kilometres burned), Bulgeria (32,000 square kilometres burned). The fires were blamed on drought conditions related to the EL Nino Climatic conditions and global warming (Myers, 2000).

Only 2.4 million square kilometres remain of the original 9.6 million square kilometres of forest in Asia. Each year in Southeast Asia, fires, logging and conversion to tree plantations and agriculture destroy an additional 244,000 square kilometres of rain forests. This destruction of the rain forests threatens many endangered species including tigers, elephants, orangutans, sumatran rhinos, and tapirs as well as hundreds of species of birds, plants and insects (Kharuk and Ranson, 2000).

According to Dei (1993) the fires have driven Orangutans, already rapidly declining due to forest clearing into populated areas, where the adults have been killed for food and the young taken for the illegal pet trade. The smoke from the fires has had tremendous human health impact. Some of these discharges contain sulphur oxide, chlorinated hydrocarbon, nitrogen oxide, carbon monoxide e.t.c. For example, carbon monoxide contains gasseous pollutant which deprives blood of oxygen. This tend to increase suffocation and inhibits metabolic process in the cells. This is dangerous to people with heart and lung diseases.

In Nigeria, the dry Sudan and Sahel zones, burning in some places has led to the disappearance of the grass vegetation leaving only fire-resistant thorny shrubs which are unpalatable to grazing animals (Areola, 1990 and Omoruyi et al, 2003).

Lumbering.

Saw-milling is the oldest and best established wood-based industry in Nigeria and the one which has made the greatest impact on the country's unreserved forests. There is a predominance of small units with a production capacity of under 283 cu. metres per year and medium sized units whose yearly production lies in the range of 566 – 2830 cu. metres (Areola, 1991). Logging in forest is done by logging firms saw-milling establishments and middlemen who obtain licenses to fell the trees.

The failure of government in tropical less developed countries to regulate timber cutting by multinational and national timber companies and to require these companies to replant cleared areas, is another major cause of deforestation. Increased demand for tropical hardwoods, especially by Japan, the United States and Britain, has encouraged governments of tropical less developed countries to deplete their forest for short-term economic gain (Winton, 1997). Japan alone consume 40% of the world's annual harvest of tropical hardwoods, despite the fact that two-thirds of Japan is covered with forests (Winton, 1997). Many countries have so depleted and degraded their tropical forests that for the foreseeable future, timber has become a non-renewable resource in these countries (Colchester, 1991). For example, in 1960 Nigeria was a leading exporter of tropical logs. By 1985 its forest had been depleted to the point where it spent 27 times more on imports of forest products than it got from exporting such products (Bernard, 2004).

Haiti was once covered with lush rainforests. When the forests were cut, the top soil on the hills washed away, and with it, Haiti was able to grow enough food to feed its people. Today, Haiti is the poorest country in the Western Hemisphere (Colchester, 1991).

Malaysia, currently the world's leading exporter of tropical logs, is cutting down trees four times faster than they are being replenished and has lost half of its forests during the past 20 years. If this continues, the country will have no forests left in 16 years (Winton, 1997). As the remaining supply of tropical timber in Asia is depleted in the 1990's, timber cutting in tropical forests will shift to Latin America and Africa. If present trends continue, by 2020 most of the world's tropical hardwoods will be depleted (Winton, 1997).

Identifying logging as one of the causes of forest loss in Nigeria, Akinsami (1996) in a study conducted in the Western part of Nigeria revealed that about 88.5 million Nigerian's depend on the forest for internal requirements of wood and wood products. According to the Federal Environmental Protection Agency (FEPA, 1998), long-term losses from deforestation has been estimated at around US $750 million per year at 1990 prices.

Fuelwood Exploitation

Bernard (2004) noted that the high level of poverty in Africa, more than 80% of the rural population and even some families in the urban centres depend on firewood and charcoal for their domestic cooking. This situation has contributed immensely to forest depletion.

According to Anderson (1990), "In low income countries the consumption of fuelwood energy by households is typically ten times the total consumption of commercial energy for all purposes, including transport and the generation of electricity; in Nigeria, it is twice the total". Anderson (1990) opined that this case study is not restricted to one part of Nigeria, but to the north and the south, and has international dimension.

2.2.4 Trends of Deforestation

Forests perform a broad range of critical environmental and climatic functions including the maintenance of constant supply of water. They harbour a wide range of flora and fauna species while at the same time having very deep economic, aesthetic, industrial and religious significance for humans. In an intricate cycle of life, the forest efficiently recycles all the living materials it contains, including the plants, animals, insects, and micro organisms.

Remarkably, this whole complex ecosystem usually requires a quality soil. Once destroyed, it may be difficult or impossible for such a forest to recuperate (Myers, 2000).

Many people earn their living from tropical forests. Besides providing a field for scientific research and for tourism, tropical forests are commercially important for such products as timber, nuts, honey, rubber and resin. Colchester (1991), noted that tropical forests are not only disappearing at an alarming rate but also shrinking fast. The fast disappearance of the forest is a global issue.

The world's tropical forests has been greatly affected by the pattern and intensity of land use by societies. The demand for agricultural land, timber and other forest products, has significantly impacted on the mode and rate of transformation of forested areas. The world's tropical forests are disappearing faster than ever. This assertion has its root on the fact that every succeeding study shows a startling acceleration of the process. According to Repetto (1998) tropical forest resources are currently undergoing depletion at an acceleration pace.

In the last 5,000 years, humans have reduced forests from roughly 50% of the earth's land surface to less than 20% and if the problem continues at present rate, Thailand will have no forest left in 25 years; the Philippines in less than 20 years, and Napal in 15 years (Miller et al, 1991). Many of the large areas of grassland in the world, such as the savannas of Africa, the Steppes of Eastern Europe and Russia, the Pampas of Argentina, and at least some of Prairies of North America, were forested before human disturbance. In the drier areas of the world such as North Africa, Greece, Italy and Australia, the deforested areas have subsequently been overgrazed, and have lost soil so rapidly that they have turned to desert (Miller; Kenneth and Tangley 1991). According to Myers (2000), of the original extent of about 9.6 million square kilometres of tropical moist forests, only about 4.8 million square kilometres was left in 1979, about 44% of the original tropical forest on the earth had already been lost. Myers estimated that forest loss had increased by 90% since 1979, while the three countries which account for half of the world's tropical forests, Brazil, Zaire and Indonesia, also account for nearly half of the annual loss. Marshall (1990) noted that three years ago, areas that seemed to remain forested for longer period of time, for instance Papua, New Guinea, Western Amazonia, Guyana and the Zaire basin are now facing a massive acceleration of logging and road construction. Repetto (1998), reported that more than 80% of the planet's natural forests have already been destroyed. What makes this environmental loss especially sad is that tropical rainforests are often destroyed for little permanent benefit. Many of these woodlands have been converted to grazing land for cattle. And the land fails to sustain the needed pasturage and is abandoned in this way. The tropical rainforests of Madagascar before human colonization are thought to have covered most of the eastern coastal plains that run the length of the island. Now most of the forest has been cleared by people and fire, leaving forest covering less than 15% of the land, mostly on slopes and rugged terrain (Miller; Kenneth and Tangley 1991).

In many tropical forest countries, roads have been constructed to gain access to timber, hydroelectricity power and minerals. In Ecuador for example, roads have been constructed by the oil companies, thereby opening the forests to a wave of settlement by landless poor settlers from the highlands, and giving the country the highest rate of deforestation in South America (Colchester, 1991). Logging roads enable landless people to enter the forest. In Africa, 75% of the land being cleared by peasant farmers are land that has been previously logged (Myers, 2000).

In Indonessia, forest colonisation by “spontaneous” settlers has been greatly facilitated by logging roads. According to Colchester (1991), in Cote d’Ivoire, it is logging roads, followed by settlement that have been the main cause of forest loss. So clear is this correlation between logging and forest colonisation that Myers has calculated that for every cubic metre of harvested timber, approximately 1/5 hectare of forest is destroyed by farmers who press in, close behind the logger (Myers, 2000).

Grazing is a major resource process in Nigeria and one which has had a profound effect on the country savanna ecosystem. Its importance in rural land use has increased progressively over the years as the forest gave way to savanna and the Fulani herdsmen expanded their areas of operation.

As in other parts of the tropics, grazing in Nigeria is characterized by a lack of range management and improvement measures. More is taken out of the environment than is put into it; fertilizer input is nil; the only nutrient inputs being from animal manure. The livestock depend entirely on native vegetation and there is virtually no cultivation of forage crops to supplement this. Grazing of domesticated animals is done in a wide variety of ecological/climatic zones with marked differences in the total annual rainfall, the duration of the wet season and the availability of dependable sources of water for animals. The one element that is common to all the zones is the availability and prominence of grass in the vegetation community (Areola, 1991).

Savanna vegetation in Nigeria covers nearly 75 percent of the country. The 1143mm isoyet which marks the northern limit of the former dry forest zone may be regarded as the southern limit of natural savanna vegetation in Nigeria. But south of this line is an irregular belt of derived savanna vegetation which, over the years has been brought into the grazing economy and is important as an all season grazing area for the far-ranging Fulani cattle species. The other savannas are usually sub-divided into Guinea, the Sudan and the Sahel savannas. The growth of grass is regulated by season and climate and it is only available to grazing animals for a limited period of the year. The Guinea and derived savanna zones provide much more adequate grazing during the dry season than other zones (Areola, 1991).

The greatest impact of grazing on the environment can be attributed to overgrazing and bush burning. Overgrazing can be traced to a number of root causes such as, the semi-arid environment and the scarcity of pasture. Overgrazing in such areas as Borno and the Sokoto-Rima basin has led to the development of ‘patched’ land surfaces due to the exposure of the land to intense insolation and increased rates of evaporation. The result is that the hardened soil surface can no longer be colonized by plants. With the removal of the vegetation and the hardening of many surfaces, infiltration of water into the soil is greatly reduced. The increased runoff thus generated has been responsible for erosion of slopes in the grazing areas. In the Sokoto – Rima basin for instance, sheet and gully erosion take place on the slopes overlooking the broad valleys. Gully erosion also occurs on the overgrazed lands of the Jos Plateau (Akosi, 2007).

Degradation of the habitat through overgrazing, over-browsing, soil trampling and compaction is a very serious problem at lick sites. Some areas are now completely devoid of vegetation cover thereby exposing the soil to erosion and intense insolation (Akosi, 2007).

In the dry Sudan and Sahel zones burning in some places has led to the disappearance of the grass vegetation leaving only the fire-resistant thorny shrubs. The same is true of sections of the Guinea savanna zone which now only carry a woody vegetation with little grass under storey. One area where the problem of bush burning may not be amenable to a simple solution is in relation to wildlife conservation, where fire appears to be double-edged sword; it promotes the growth of fresh green foliage which attracts game but at the same time it kills many wild animals. Burning becomes a major concern in those areas declared as grazing reserves which are also wildlife conservation zones where hunting is forbidden. The Fulani frequently set these grazing reserves on fire, which further degrade the environment (Akosi, 2007).

The forests vegetation on the other hand comprise of swamp forests, tropical rain forest and secondary forest re-growths. The forest tree cover undoubtedly influences the soil physical and chemical properties (Aborishade and Aweto, 1990; Isichei and Muoghalu, 1992). The southern part of the country is dominated by the forests vegetation. Various human activities in the form of agricultural cultivation, lumbering, fuel wood exploitation, road construction and red earth quarrying and bush fires, has impacted negatively in the forest ecosystem.

In Nigeria, serious exploitation of forests is occurring at an alarming rate. The forest resources in Nigeria are undergoing depletion at acceleration pace following the negative impact of human activities in the forest ecosystem. Lumbering and agricultural cultivation has been responsible for the depleted forest resources in Ogun, Ondo, and Edo (Akosi, 2007). The demand for agricultural land, timber and other forest products, has significantly impacted on the mode and rate of transformation of forested areas. It results in permanent destruction of indigenous forests and woodlands, and constitutes one of the most critical environmental problems facing the world today (Fuwape, 2004). In Southern Nigeria, with emphasis on Edo, Delta, Ogun and Ondo States, the natural forest cover has been largely destroyed owing to centuries of shifting cultivation and other agricultural practices such as plantation of tree crops, the development of settlement and transportation network. There has been increasing concern about the loss of species and reduction in the genetic diversity of trees. This concern arose because of the far-reaching implications of large-scale destruction of forest cover. For instance, an extensive reduction in the forest tree species may lead to loss of ecosystem stability and function. The rate of tropical forest degradation exceeds 15 x 10^6 hectares annually, resulting in extensive reduction of forest landscape (Fuwape, 2004).

FAO (1990) forecasted complete exhaustion of Nigeria's existing forest resources before the end of the 21^{st} century and gave a projected consumption for Nigeria in 1995 of between 9.5 million M^3 and 12.5 million M^3 (round wood equivalent), for saw wood and plywood, plus between 3.3 million M^3 and 7.2 M^3 for fuelwood and poles, for an estimated population of between 122.5 million and 138.5 million. Such rate of consumption of wood will exhaust the 20,000 km^2 of highest forest reserves in ten to fifteen years and the 75,000km^2 of savanna reserves (for fuelwood) in about three years (FAO, 1990). Between 1981 and 1994, Nigeria is said to have lost 3.7 million hectares of forests. Presently, FAO in 2007 estimated only a paltry 4% of Nigeria's rainforest cover left. The loss is accelerating at an annual rate of 3.5% with the attendant loss of bio-diversity. About 484 plant species in Nigeria are said to be under threat of extinction (FAO, 2007).

And if the present trend of deforestation continues, substantial tracts of moist tropical forests will be under threat of extinction (Colchester, 1991).

2.2.5 Methodological Approaches

Different methodological approaches have been applied in the study of deforestation and soil in the rainforest ecosystem. These approaches are discussed under the following headings:

Area Measure:

This is achieved by the application of the technique of quadrant analysis. The study area is divided into quadrant from which easy assessments are made for data collection (Bernard, 2004).

It may be more appropriate to select sample on the basis of small units of equally spaced squares. These provide greater coverage of an area of study than the points or lines. Quadrant are areas, ideally of the same size, that can be used in a fashion similar to traverses (Kunde, 1995). The area of study can be divided into small equal sizes squares and these squares treated as sampling units, and it is possible to obtain the proportions of the unit area of all such squares covered by each characteristics.

Each quadrant is, in effect one observation. The basic difference between this type of sample and points or traverse is that the area of the quadrant is a fundamental property, which affects the number of observations used. Since each quadrant is, in effect one observation, if the area of the quadrant is quite large relative to the entire area comprising the population being sampled, then the number of quadrants needed is very few. But if the size of the quadrants is small relative to the area of the population being sampled, then the number of quadrants needed would be larger (Bachi, 1993).

In vegetation sampling, a square quadrant is usually favoured and the sizes of this quadrant depend on the characteristics of the plant communities. In vegetation sampling, a quadrant can be placed either randomly or systematically. A random sampling could be achieved by using a random table. While the systematic quadrant is carried out by placing the frame by plotting quadrant along a line or over a grid (Bachi, 1993).

However, it must be emphasized that the number of quadrant recorded are important in determining the quality of result obtained from the samples. The more quadrant samples, the more accuracy of result.

This method has been used by some scholars in the study of deforestation and soil of the deforested areas Kunde (1995) in his study adopted the quadrant technique in data collection. The study area was divided into five divisions for the easy assessment of data collection. At each sampling site, a quadrant of 15m x 15m was adopted. And within each quadrant, samples were collected randomly at an equidistant point of 7.5 metres at a predetermined depth of 0 – 15cm layer from the topsoil.

Chidumayo and Kwibisa (2002) in their study on effects of deforestation on grass biomass and soil nutrient status in Miombo Woodland in Zambia, adopted the quadrant technique in data collection. In the study, samples were collected from each cleared plot and from the adjacent uncut plot. In the centre of each sampled plot, a 6m x 5m sub-plot consisting of a grid of 30 1m x 1m quadrants was permanently marked by stakes.

(Ogunleye et al, 2004) in their study on Impact of farming activities on vegetation in Olokemeji forest reserve in Nigeria, adopted the quadrant technique in data collection. The study area was divided into three zones for the easy assessment of data. The zones are: natural forest (zone 1), plantation (zone 2), and the fallow area (zone 3). The 3 major zones were used as basis for the selection of sample plots. In each of the 3 major study zones, a 1000 metre long transect was cut. Along each transect, 25 (40m x 50m) sample plots were laid with the aid of a compass and pegs from where ten plots were randomly selected for enumeration.

These studies exploited the quadrant technique in data collection. However, Kunde (1995) adopted a quadrant size of 15m x 15m, Chidumayo and Kwibisa (2002) adopted 6m x 5m, and (Ogunleye et al, 2004) adopted 40m x 50m.

The quadrant technique can be used in determining the physical or spatial distribution of phenomenon. However, it has its own short coming, for example:

(a) It is subject to the size of a grid.

(b) There is also the consequent problem of determining the appropriate size of the grid.

(c) It is silent on the distance between the phenomenon of interest.

Despite these limitations, it remains one of the valid method of soil-vegetation data collection over the years. This study adopted this method in data collection.

Soil Measure:

The investigation of soil is carried out by first collecting samples from the study area and then taken to the laboratory for analysis (Chidumayo and Kwibisa, 2002).

Soil study usually involves the investigation of soil in the field. Soil study is a multi-stage project. In other word, the study proceeds in stages. The first stage in any soil study is the preliminary investigation. The preliminary stage of a soil study offers the investigator opportunity of collecting first hand information about the initial conditions of the area, demarcate and delimit area of study precisely (Kunde, 1995).

The second stage of soil study involves the field equipments needed for the study. There is no standard list of soil survey equipment; the types as well as the number of the different equipments/instruments depend on the scale of investigation and the soil properties being investigated. In situation where standard equipment is not available, we sometimes make improvisation. For instance, in collecting soil samples we may use sharp cutlass instead of auger or shovel (Kunde, 1995).

Some of the common equipment and material used during soil survey are:

1. Base Map

This normally includes the topographical map, soil map, vegetation and landuse map. These base maps are usually covered with transparent overlay on which sampling sites and soil boundaries can be drawn. Aerial photographs can also be used for the same purpose.

2. Compass (prismatic compass)

3. Abney level

4. Altimeter or aneroid

5. Clinometer or theodolite
6. Ranging poles
7. Auger or cover
8. Spade or shovel, pick-axes trowel
9. Tape
10. Graduated measuring tyrods
11. Soil testing kit
12. Munsell colour chart
13. Containers, polythene bags etc
14. Sundry items like survey note book, pen and pencil.
15. Soil proforma.

According to Bernard, (2004) the number of samples for a particular study depends on:

a. The objective of the study
b. The spatial variability of properties under investigation.
c. The coverage required for the statistical method of analysis.
d. Cost of sampling (Cost of the field work and laboratory analysis).

There are many procedures for selecting samples from the population. However, the ultimate issue is that the samples selected must be representative of the population under investigation. To ensure representation we can make use of any or a combination of the following sampling procedures:

Simple Random Sampling:

The principle of random sampling is that every element of the population is given an equal chance of being selected for study. The exact size of population must be known. The first step in random sampling is to construct a list of all individual sample units (sample frame) in the population being sampled. Each element is allotted a number. The table of random samples could be used to select a random sample.

Systematic sampling:

With this technique, each element in the population is allotted a number. The researcher may select every 10th, 20th of Nth element of a population until the desired sample size is selected.

Stratified Random Sampling:

When a population is heterogeneous, it might be necessary to first stratify by dividing it into a set of mutually exclusive sub-population or strata, which could be race, sex and religion. Random samples are then selected from each stratum.

Cluster sampling:

In cluster sampling, we divide the population into groups or clusters and then select a random sample of these clusters. We assume that the individual element are representative of the population as a whole. Clusters sampling is mostly used in the situations where the units in the population exist in natural groups.

Multi Stage Sampling:

When a population is greatly heterogeneous and it is difficult to develop the sample frame of individual elements, it might be necessary to select random samples in stages. For example, in order to obtain a representative sample of school children in a large city, it would be more convenient first to draw a random sample of schools and then within each selected school, to draw a sample of children.

These five procedures are called probability – sampling procedures and they can be combined and used together. But the choice of a particular sampling procedure should be based on its relative advantages over the others with respect to a particular study (Akinbode, 1996).

The next stage is the collection of data from the field with adequate method suitable to the particular study, with the use of the field equipments. The samples collected are placed in a polythene bag or container, and sealed tightly to prevent water evaporation. The next stage is laboratory analysis of the collected data from the field (Bernard, 2004).

This method has been used by some scholars in the study of deforestation and soil of deforested areas, (Oya; Tokashiki and Shimo 1995) in their study on physical and chemical properties of soil in the reclaimed land and forest of Iriomote Island in Japan, adopted the soil measurement technique. The experiment plot A was under forest as control DG plot that was abandoned after grass cultivation for 3 years after clearing the forest by a rakedozer, DN plot that was left unused after clearing by a rakedozer, EG plot that was abandoned after grass cultivation after clearing the forest by a bulldozer, and EN plot that was left unused after clearing by a bulldozer. The DG and DN plots were prepared by clearing forest by a rakedozer to leave the original surface soil in situ but the EG and EN plots were prepared by a bulldozer to flatten the ground. That is, the surface soil to a depth of 1m or so, was moved to lower ground and the sub-surface soil was exposed by the use of bulldozer. These clearing and preparation was done in 1976.

Three surface soil samples (0 – 15cm) were collected from each plot in 1976, 1979 and 1991. The soils were analyzed to determine physical and chemical properties. The soils status of available phosphate and exchangeable A1. Soil phosphate was extracted with 0.002 NH_2S0_4 and spectrophotometrically determined by Guinea-green B method at 630nm wave length, and designated as available phosphate. Exchangeable A1 was extracted 5 times with 1N KCI solution at a ratio of soil to solution 1:10. The extracted A1 and hydrogen ions were titrated with 0.1N sodium hydroxide then back titrated for A1 with 1N Hcl after an addition of 4% sodium fluoride. The relation between soil pH and exchangeable A1 was expressed by a power regression.

Chidumayo and Kwibisa (2002) in their study on effects of deforestation on grass biomass and soil nutrient status in Miombo woodland in Zambia, adopted the soil measurement technique.

At the centre of each quadrant of 1m x 1m, a soil sample was collected with an auger from 0 – 30cm depth (topsoil) and the whole sample placed in a polythene bag, labeled and sealed before laboratory analysis was done. No soil samples were collected in 1994. The samples were analyzed for pH (except in 1999), total organic matter (OM) and nitrogen (N) and available phosphorus (Av. P). Soil bulk density was estimated from samples collected in June 1991. From each cut plot and the adjacent uncut plot, four soil samples were collected from the centre of the plot with cores. A cylindrical metal sampler with a diameter of 3.6cm was driven into the soil to depth of 20cm and carefully removed to preserve the sample volume. The soil sample was immediately weighed before transportation to a laboratory for oven-drying at 105^0c for 24 hours and re-weighed. Bulk density was then calculated as oven-dry mass (Mg) per volume (M^3).

The soil nutrient data were compared for significant differences using a student t-test and analysis of variance statistical techniques.

In these studies, (Oya; Tokashiki and Shimo 1995) examined only two soil elements of available phosphate and exchangeable A1. Chidumayo and Kwibisa (2002) examined four soil elements of organic matter, nitrogen, soil pH and available phosphorus (Av. P). While (Oya.; Tokashiki and Shimo 1995) carried out their study for a period of 3 years. Chidumayo and Kwibisa (2002) carried out their study for a period of 10 years, and they adopted the student t-test statistical technique. While Oya et al (1995) adopted the power regression model.

Soil survey is carried out with the aim to know the detailed pattern of the soil or the degree of variation of single soil properties. This study adopted this method in data collection.

Irrespective of the different methodological approaches, the data collected are compared with those from the adjoining forests to ascertain the impact which the particular study is based.

Table 2.1: Review of Methods on Deforestation Adopted by Previous Scholars

Authors / Year	Title / Place	Methods Adopted	Contribution to Knowledge	Criticism
(Oya, K.; Tokashiki, Y and Shimo, M. 1995)	Changes in physical and chemical properties of soil in the reclaimed land and forest of iriomote Island in Japan	The soil measure technique of field survey method was adopted. And the regression model was used in validating the result	The result enriched existing body of knowledge on Deforestation and soil.	The study dic not examine concentration of metals in the soil
Mesgari and Ranjbar (2003)	Analysis and Estimation of deforestation using satellite imagery and GIS in Arasbaran in India	The Aerial Technique method was adopted in this study. Satellite images and topo maps were used and the regression statistical technique was adopted	The result provided practical value in solving problems in Arasbaran in India, and also contributed to body of knowledge	The study dic not examine particle size composition, potassium an sodium.
Kunde (1995)	The characteristics of soils under permanent and shifting cultivation in the Miombo woodland in Zambia	The soil measure technique of field survey method was adopted. And the student t-test technique was used in validating the result.	The result of the study played a useful role for planning purposes, and also contributed to body of knowledge	The study dic not examine soil elements of CEC, available phosphorus and concentration of metals in the soil
Chidumayo and Kwibisa (2002)	Effects of Deforestation on grass biomass and soil nutrient status in Miombo woodland in Zambia	The soil and vegetation measure techniques were adopted for this study. The student t - test and analysis of variance was also adopted.	The result of the study provided practical value in solving problem, and contributed to theory.	The study dic not examine particle size composition
Ogunleye, et al (2004)	Impact of farming Activities on vegetation in Olokemeji forest reserve in Nigeria	The floristic method of vegetation measure and questionnaire was	The result of the study provided value to policy development	The study dic not examine particle size composition, CEC,

		adopted for this study. The Simpson diversity index and descriptive statistical technique was adopted	and contributed to body of knowledge.	potassium an sodium.
Oke and Oyun (1997)	Conversion of forest to plantation in Nigeria	The floristic method of vegetation measure was adopted for this study. The analysis of variance statistical technique was used in validating the result.	The result of the study provided practical value in solving problems and contributed to body of knowledge	The study dic not examine available phosphorus, CEC, magnesium and calcium.
Bernard (2004)	The Causes and Control of Deforestation in forest zone of Rivers State	The questionnaire method was adopted in this study and the percentage method was used in validating the result.	The result of the study provided value to policy development and contributed to body of knowledge	The study dic not examine **concentration** of heavy metals in the soil.

Source: Ifende (2010)

(Oya, K.; Tokashiki, Y and Shimo, M. 1995) and Kunde (1995) adopted soil measure technique of field survey method in their various studies, and the student t-test and regression statistical techniques were employed in validating the result. Chidumayo and Kwibisa (2002) adopted the soil and vegetation measure techniques in their study, and the student t-test and analysis of variance were employed in validating the result. Mesgari and Ranjbar (2003) adopted the aerial technique, Ogunleye et al (2004) adopted the floristic method of vegetation measure and Oke and Oyun (1997) also adopted the floristic method of vegetation measure. The regression, Simpson diversity index and descriptive statistical techniques were employed in validating the results (Table 2.1). While Bernard (2004) adopted the questionnaire method, and employed the percentage method in validating the result.

2.2.6 Problems of Deforestation

In this section, related studies on the impact of deforestation on forest ecosystem was reviewed.

Areola (1992) and Ifende (2010) observed that forest soils losses its fertility during the period of cropping and regains it during the fallow period under shifting cultivation practice. Clearing and burning precede cropping, and it has been shown in this study that this practice may result in decline in organic matter and soil nutrient status as a result of the exposure of the soil to the effects of rain and sun.

Lal (2000) in his study of the effects of clearing on tropical forest soils, observed a decline in organic matter from 3.65% to 1.5% and a decline in Nitrogen from 0.36% to 0.17% within a period of three years following clearing in tropical forest.

However both studies by Areola (1992) and Lal (2000) did not point to other impacts of exposure of the soils to the effects of rain and sun, like soil desiccation and accelerated soil erosion.

Burning on the other hand has been widely accepted as being harmful to the soil nutrient status, especially in the Savanna areas where nearly all the vegetation is burnt annually and the nutrient cycling is interrupted as there will be no more vegetation to supply litter to the soil (Asadu and Nweke, 2001).

The fear has often been expressed that the burning of the cleared vegetation may destroy organic matter (Omoruyi, S.A.; Orhue, U.X.; Akerobo, A.A and Aghimien, C.I. 2003). But Asadu and Nweke (2001) have pointed out that it is only the non humidified organic litter that is burnt and there has been no evidence of any loss of humidified organic matter from the soil itself. They further noted that data from Ghana, Nigeria, Liberia and Srilanka do not indicate any significant changes in the carbon and nitrogen content of soil following burning. However, frequent burning of the vegetation on the same piece of land may lead to a progressive desiccation and baking of soil particularly since the fallow period is drastically reduced in many parts of Nigeria.

Asadu and Nweke (2001) observed in their study of soil under shifting cultivation that burning causes loss of nitrogen and adversely affect soil microbial and soil physical and chemical properties, and also raises soil pH. However, Asadu and Nweke (2001) and Ezeaku (2002) argued that burning is not totally harmful to the soil. They contended that burning has a partial sterilization effect and it increases the supply of nutrients in the soil in the form of ash, potash and phosphorus. Vine (2003) noted that the soil becomes friable after burning, thereby facilitating the penetration of roots.

Areola (1990) and Angelsen and Kaimowitz (2010) noted that the incidence of annual bush fires in the forest region has increased, and this has been aided by the very severe dry seasons. These fires sometimes spread from the fallowlands to consume tree and fruit crop farms. Thus, many cocoa farms and many banana and plantain plantations are destroyed from time to time. It is noteworthy that Siam weed now forms the undergrowth in many forest regrowths and in weedy tree crop plantations. Most of the secondary forest reserves suffer severe burning during the dry season. According to him, the forest reserves in the humid southern part of Nigeria that used to be heaven free from bush fires and from land exposure, is seriously affected. Presently, the incidence of burning and the degree of land exposure have increased appreciably with the replacement of the natural forest with plantations of exotic trees, the major ones being the deciduous *tectona grandis* and *gmelina arborea*.

The result of all this is that much of the land area covered by the natural forests, will be exposed. And this will pave way for the potential danger of desiccation and other soil related problems like accelerated soil erosion Areola (1990).

The studies by (Asadu and Nweke, 2001; Ezeaku, 2002; Vine, 2003) on the effect of burning on soils, has adequately expressed the negative and positive impact on the physical and chemical properties of the soil. However, these various studies did not emphasize the threat of wildfire to the genetic resources of a range of species.

Areola (1991) noted that once the forest is cleared the soils tend to dry out progressively and some may develop clay pans and regeneration is made difficult. According to them, pressure on the land due to high rural population densities, the practice of shifting cultivation and annual bush burning all combine to degrade the forest into derived savanna in which susceptible forest trees are progressively eliminated leaving only fire tolerant Savanna species such as West African Locust bean tree, shea butter tree etc. However, these studies did not address the issue of physical and chemical properties of the soil like particle size composition, available phosphorus, soil organic matter, total nitrogen and soil pH.

The destruction of rainforest ecosystem results in the conversion of relatively continuous ecosystem into patches of natural rainforests which are surrounded by different land use such as agricultural production and urban development (Saunders, 1991; Noss, 1999; Lambin, 2003 and Panta, 2009). Rainforest destruction is said to decrease the diversity of tree species, biomass parameters of the vegetation and the population of trees due to the reduced size of the ecosystems, climatic and biological changes associated with habitat edges (Saunders, 1991; Lande, 1998; Yahner, 1998 and Ifende 2010).

Deforestation results in the reduction of forest ecosystems. As a result of reduced areas which were originally covered by rainforest tree species, the population of trees present tends to reduce following the net impact of deforestation (Ewens, 1990; Lawton, 1995; Fitzsimmons, 2003). The population in deforested ecosystems are more likely to become extinct, and consequently should lead to an overall reduction in biological diversity in the region (Harrison and Fahrig, 1995). These studies did not address the issue of impact of deforestation on the physical and chemical properties of soil in the rainforest ecosystem.

There has been increasing concern about the loss of species and reduction in the genetic diversity of trees. This concern arose because of the far-reaching implications of large-scale destruction of forest cover. For instance, an extensive reduction in the forest tree species may lead to a hitch in ecosystem stability and function. The rate of tropical rainforest degradation results in extensive reduction of forest landscape (Peters, 2001; Lavely and Manson, 2006).

Diversity is a universal characteristic of living systems as exemplified by the dynamics of the human environment which is constantly changing. Some of these changes are cyclical, while others are less predictable. Even in the cyclical changes, a strong random component is always present. For example, the onset of the raining season may be delayed, bringing about a delay in the flowering and fruiting of trees. Drastic environmental change is a major source of species loss in the fossil record (Signor, 1990).

Under pronounced pressure on the forest, the regeneration of forest trees is inhibited. This according to Aweto (2001) is due mainly to lack of mature forest trees, owing to widespread deforestation and to site burning prior to cultivation, which destroys seeds of trees in the ecosystem.

Man has not only deliberately produced new species and varieties of plants, but he has also assisted in natural evolution by altering the environment. In a stable environment, evolution is very slow as there is little need for change, but a changing environment results in adaptation and thus the evolution of new species. However, man’s interference with the habitat of plants has also resulted in the extinction of those species unable to adapt (Lawton, 1995).

Martin (2008) and Hyde (2010) observed that large-scale timber extraction by distant communities serving international markets leads to species diversity and species loss. The extraction of trees leads to local loss of forest resources which could be vital means of subsistence and income generation to the local communities. Over the years, logging business has developed in Nigeria and many wood based industries have been established and depend largely on the forest tree species (Oke and Oyun, 1997). Other factors which have contributed to the rapid disappearance of the natural forest are road construction, industrial development and urban expansion (Oke and Oyun, 1997). Population growth results in the springing up of new settlements to accommodate new families and existing towns grow into major urban centres hereby swallowing up adjoining farmland and pushing back forest boundaries to create new farmlands (Nagendra, H.; Southworth, J.; Karna, B. and Karmacharya, M. 2004; Afolabi, 2007).

The widespread cutting of wood for fuel particularly in the rural areas as a source of energy also leads to species loss (Adesina, 1998; Afolabi, 2007). In the semi-arid regions, roots of shrubs are dug up for fuel wood while grasses are cut off for roofing and fencing.

Forest clearing for subsistence food production has been responsible for the loss of biological resources. Of all the causes of bio-diversity destruction, agricultural production is the most critical. The diversity of the originally grown forests are degraded due to the adoption of some silvicultural practices borrowed from the temperate environment. These practices have generally been unsuccessful in the tropical environment (Mull, 1993, and Ojima, 1994). These silvicultural practices consider forests as interdependent, high diversity ecosystems of potential multiple value (Panayotou and Auhton, 1992). Some what less destructive to species diversity but still very damaging are silvicultural treatments such as girdling and poisoning of "non-commercial" trees in order to encourage favourable species to develop more rapidly than they would in the natural setting (Mull, 1993).

Wildfire is a real threat to forests and the genetic resources of a range of species. It has been established that fire accidents have reduced forest areas of natural ecosystems (Goudie, 2008). Wildfire is known to have pronounced effect on the vegetation. Fire can kill parts of a tree plant or the entire plant, depending on the intensity and duration, of burning (Adesina, 2006; Hyde 2010).

Variation in the microclimatic parameters between the core and periphery of rainforest ecosystems has significant impact on the type of tree species contained in the core and periphery of the habitats. Studies by Aizen and Feinsinger (1994); Santos and Telleria (1994) suggest that edge effects and reduced size of forest as well as climatic condition can influence various life history stages
of plants, although, none of these have been associated with actual changes in population viability.

The boundary of an ecosystem constructs it edge. Usually, this boundary or zone of interface is not as suitable as the area of the ecosystem because of the breeding and feeding of species. Besides, some periphery areas are colonized with edge species which will compete with species originally found in the ecosystem (Spellerberg and Sawyer, 1999).

In examining habitat degradation and demographic change for plants, Jules (1998) focused on determining if habitat fragmentation has resulted in demographic changes associated with increased extinction risks and also assessed the proximal mechanisms (such as microlimate and edge effects) underlying the changes. However, the result of this study revealed that habitat destruction leads to increased risk of extinction, and that demographic changes for a plant largely depend on the microlimate and edge effects.

In recent times, edge effects appear to be a major cause of change in plant communities. In rainforest ecosystems, the harsh external climate is buffered by dense canopy cover, but this buffering breaks down near forest edges (Jules, 1998), and may lead to higher mortality of plants. Strong turbulence can result when wind strike abrupt forest edges, increasing rates of wind throw and forest structural damage (Jules, 1998). However, degraded rainforests often exhibit a proliferation of vines, bianas, and secondary vegetation near edges (Jules, 1998).

The studies by these various scholars have been able to examine the interference of man in the ecosystem and its impact on habitat degradation and demographic change in plants. However, the issue of soil physical and chemical characteristics was not addressed.

Areola (1991) and Ifende (2010) noted that tropical forest, lived precariously on the products of its own decay, and once a forest area is destroyed, regeneration is very slow. With the removal of the vegetation, the ecosystem loses a great deal of energy and nutrient-rich material; the nutrient cycle is greatly disturbed and soil humus content falls. The change in microclimatic conditions, especially the drier air and the more intensive insolation on the ground surface, will promote faster rates of organic matter decomposition.

This study has adequately examined the impact of deforestation on the soil characteristics of forest soils. However, soil elements of soil pH, available phosphorus and cation exchange capacity (CEC) was not addressed.

Aweto (1998), observed that organic content of the soil, being more exposed to insolation, undergoes rapid decomposition and oxidation, and the soil water regime is altered. Moreso, he pointed out that changes take place in organic matter
and nutrient contents of topsoils under fallow of different ages and a mature secondary forest, when they are cleared. These negative feed-backs of forest degradation on the environment contribute to the slow pace of natural regeneration of emergent forest species. The faunal population is also somewhat affected as their habitat is destroyed or greatly modified.

In the light of the foregoing, this study did not examine soil elements like total nitrogen, available phosphorus, soil pH and cation exchange capacity (CEC).

Logging company are usually given short-term permission to cut timber, so the workers are directed to take everything of value. As the economic trees fall; they are connected by vines. Heavy track-laying vehicles break through the dense vegetation to haul out the logs, compacting the thin soil until it is virtually useless (Bernard, 2004). The roads that loggers leave behind open up a previously inaccessible region. Then come settlers, landless thousands seeking an opportunity to make a living on the newly accessible land. Their slash and burn farming method finishes off the remaining trees, allowing heavy rains to wash away the thin topsoil (Bernard, 2004 and Stenstrom, 2010). This study pointed out the danger of logging roads on soil. However, the degree of impact on the physical and chemical properties of the soil was not addressed.

Areola (1991) noted that the first and most noticeable impact of oil exploration was the modification of the vegetation and the physical landscape. The exploration and drilling activities involved a lot of road cutting; the transporting of heavy drilling rig equipments from one location to another, the laying of pipelines across thick forests, swamps and river channels; and the erection of drilling platforms, storage depots and human dwellings. All these activities resulted in a great deal of forest and swamp clearance, land drainage and consolidation. All these activities affect the structural balance of the soils of the affected areas.

This study has adequately expressed the impact of mining and drilling activities on the soil ecosystem. However, the physical and chemical properties of the soil was not addressed.

From the review of literature above, it can be deduced that several studies have been conducted on forest ecosystem as well as effects of deforestation on soil fertility and loss in bio-diversity. However, the studies as conducted were concentrated in the dry forest zone of South Western Nigeria, while the wet forest zone of South-South Nigeria was not addressed. Most of the conducted studies, were restricted on issues on loss in bio-diversity as a result of deforestation, while the effect on soil nutrients was not addressed. The few studies that addressed the issue of soil nutirients, only examined soil elements of organic matter, total nitrogen and exchangeable magnesium, while other soil elements of available phosphorus, soil pH and cation exchange capacity (CEC) was not addressed. Arising from these gaps, it is therefore necessary to conduct a study of this type in the study area.

CHAPTER THREE

RESEARCH METHODS

3.1 Research Design

This study adopted the experimental research design which involves the collection of soil samples from deforested and forested plots for laboratory analysis. Moreso, it involved the administration of questionnaires and measurements of vegetation physiognomy of deforested and adjoining natural forested areas in Delta State, with adjoining natural forested area being the control. In this chapter effort is made to discuss the sources and types of data, the method of data collection, statistical techniques and reliability/validity of instrument.

3.2 Sources and Types of Data Collected

The data used in this study were derived from primary source. The data include soil samples, tree height, tree diameter and tree species population from deforested and adjoining matured forest, questionnaires were also administered to respondents. In addition, affected sites were visited to identify tree species and to ascertain or measure the level of deforestation and degradation that has taken place.

3.3 Sampling Frame

Delta State was stratified into three zones based on the existing ecological zones in Delta State. In each of the three zones, four study sites was choosen for the study, based on the presence of deforested and adjoining natural forest in the area. This was arrived at on the basis of the land area under consideration being delineated into twelve locations, made up of Akwukwu-Igbo, Ubulu-Ukwu, Emu-Uno, Okpai, Aradhe, Oleh, Oto-Owhe, Ubeji, Agbarho,

Otor-Udu, Oghara and Ewvreni (Figure 3.1). The stratified random sampling technique was adopted in sample collection and distribution of questionnaires.

3.4 **Field Equipments**

The Equipments used for the field survey, include:

(a) Metal Cylindrical Core Sampler.

(b) Cutlass.

(c) Scale Ruler.

(d) Metal Measuring Tape.

(a) Metal Cylindrical Core Sampler. A metal cylindrical sampler with a diameter of 3.6cm was used to collect soil samples and carefully removed to preserve the sample volume.

(b) Cutlass / Trowel. The cutlass was used to create foot path in the site of study, while the trowel was used in collecting soil samples.

(c) Scale Ruler. The scale ruler is a field instrument that was used to measure samples depths in the field.

(d) Metal Measuring Tape. The tape was used in delimiting the study area.

The location of the sample sites in the study area is represented in Figure 3.1.

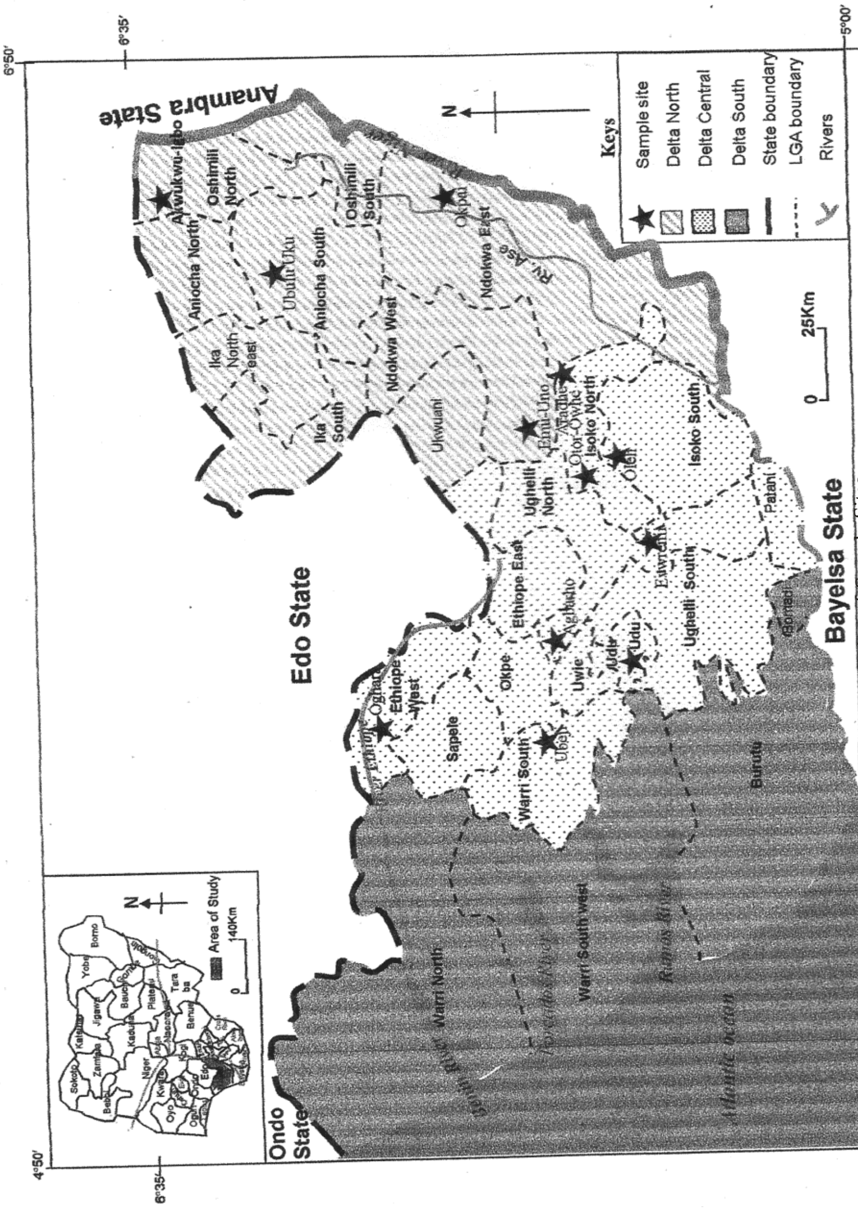


Fig. 3.1: Delta State: Location of Sample Sites
Source: Modified after Ministry of Lands, Survey and Urban Development, Abuja

Other field materials that were used for the survey include: Labels, polythene bags, sieve, pocket notebook and pen.

Labels

Labels are usually tags attached to samples collected in the field for easy identification during analysis.

Polythene bags. Polythene bags are containers that are more durable in sample collection. They are usually used in collecting samples from the field, and they are tied tightly to prevent evaporation.

Sieve

Sieve is used to filter soil particles

Pocket Notebook and Pen

Jotter and pen were essential for the researcher during the field survey, for this recording details observed in the field.

3.5 Methods of Data Collection

The twelve selected locations from adjoining natural forest and deforested plots in the study area were used as sampling sites, the procedure adopted for data generation, involves soil samples and tree species collection from both deforested and adjoining natural forest in the study area.

The stratified random sampling technique (Wanke, 2009) was used to select two (2) sample sites from each of the twelve (12) locations, one (1) sample site from the deforested and the other from the forested sites. Thus (12) deforested and (12) forested sites were selected, making a total of 24 sites in all. The adjoining natural forest served as control sites that were used to compare with the twelve (12) deforested sites.

In the study area, 24 equidistance plots were marked out at 60m x 60m apart, from which data were collected. Each of these plots, which measured 60m x 60m, was adopted for the size of the adjoining rainforest plots selected. The plots were all divided into quadrants of 1m x 1m to facilitate data collection and effective evaluation. Two (2) soil samples was collected with the aid of core sampler from 0-15cm layer of the topsoil and 15-30cm layer from the subsoil in each locations of deforested and adjoing natural forested plots in each month, making a total of 48 soil samples collected in a single collection per month. In all, a total of 576 soil samples were collected for a period of one (1) year. This was done to account for the seasonal variation in soil characteristics. Soil samples were collected from the four soil management methods of fallow, tillage, soil amendments and slash and burn plots, in each of the three regions of Delta State where yam and cassava are cultivated. The choice of crops was predicated on the fact that yam and cassava are the major crops cultivated in the area. Soil samples collected were placed in a labeled polythene bags for easy identification, and taken to the laboratory for analysis. The soil samples which were collected for a period of one (1) year, were analyzed for properties such as particle size distribution, organic matter, total nitrogen, soil pH, available phosphorus, CEC, and exchangeable bases- potassium, sodium, magnesium and calcium. The soil bulk density was estimated from samples collected. The soil sample was immediately weighed before taken to the laboratory for oven-drying at 105^0C for 24 hours and re-wieghed. Bulk density was then calculated as oven-dry mass (mg) per volume (M^3).

1m x 1m quadrant was used in collecting data on vegetation physiognomy of tree height, diameter and tree species population. Tree height was determined by using Abney level. This was achieved by standing some distance away from the trees to determine the angle of elevation on the top of the trees. The trees diameter was ascertained by first measuring their girths at breast heights using a girthing tape, and converted into diameter values. All trees population of ≥ 10m tall were identified by species enumerated and recorded at the time of establishment in line with Ogunleye (2004) method of data collection.

The yield of yam and cassava harvested were weighed in kilogram per plot (20m x 20m) and were expressed in tons per hectare (He) of yam and cassava farm harvested in Delta State . Moreso, soil nutrients of pH, OC, Mg, Na, K, Ca, P, and CEC were used in determining the relationship between crop yield (yam and cassava) and soil fertility.

Also, a total of one thousand two hundred (1,200) questionnaires were administered to respondents of the deforested communities. The questionnaires were distributed at random among the twelve (12) deforested communities to ensure an even distribution of questionnaire in the study area (Lavely and Mason, 2006). The questionnaires were further administered to respondents of the deforested areas.

3.6 Methods of Data Analysis

Data were analysed through laboratory and statistical methods.

3.6.1 Laboratory Analysis

With the exception of samples collected for bulk density determination, all the other soil samples were air dried at room temperature at 105^0C for 24 hours, passed through a 2mm sieve and analysed for:

i) Particle size composition by hydrometer method.

ii) Organic carbon by chromic acid digestion.

iii) Total nitrogen by regular micro - kjeldahl method.

iv) Available phosphorus by Bray’s PN solution.

v) Soil pH was determined potentiometrically in distilled water.

vi) Determination of cation exchange capacity and exchangeable bases was determined by percolation method.

A. Determination of Soil Particle Size.

This refers to the relative proportions of sand, silt and clay in the soil influences not only the structure, consistence and stability of the soil but also the ability of the soil to hold and exchange nutrients. It also determines soil response to fertilizer application in agricultural lands (Chidumayo and Kwibisa, 2002).

Experimental Procedure involved the following:

i) Weigh 100gms of soil sample into a beaker.

ii) Add 50ml of 3% 0.1M of NaoH solution, and stir at interval of 5 minutes for about 30 minutes to digest the solution.

iii) After about 1 hour pour the solution into a measuring cylinder and fill it with water to 100ML mark.

iv) Stir the solution very well using stopper to cork the cylinder.

v) Invert or shake the cylinder for 1minute reading, put a hydrometer into the cylinder and allow it to settle. After the 1 minute, take the reading of the hydrometer, then note the temperature of the solution and also record the time.

vi) Second reading of the hydrometer is also taken after 2 hours, temperature of the solution and time were also recorded.

Calculation was done as follows:

Let hydrometer reading at 1 minute = H1

Let hydrometer reading at 2 hours = H2

Temperature at 1 minute = T1

Temperature at 2 hours = T2

Temperature correction to be added to

Hydrometer reading = $0.2 (T - 19.5^{0c})$.

Where T = degree centigrade.

a) % SAND CONTENT IS:

$100.0 - (H_1 + 0.2) (T_2 - 19.5^{0C}) - 2.0)2$

b) % CLAY CONTENT IS

$(H_2 + 0.2) (T_2 - 19.5^{0C}) - 2.0)2$

c) % SILT CONTENT IS:

100.0 - (% SAND + % CLAY).

B. Determination of Soil pH

This is a measure of hydrogen ion concentration in the soil (Bernard, 2004). Soil pH is generally regarded as a very important soil property because it controls the amount of nutrient available to plants. It tends to correlate with other soil properties such as the base saturation. The soil pH may either be acidic or alkaline. There are two ions that are responsible for the state of the soil. They are hydrogen ions (H+) and hydroxide ions (0H-). When the concentration of hydrogen ions is greater than the hydroxyl ions, such a soil is referred to as alkaline. On the other hand, when the level of hydrogen ions is equal to that of hydroxyl ions, the soil is referred to as being neutral.

Experimental Procedure

Soil pH in H_20 (1:1 soil to water ratio)

i) Weigh 20g of air -dry soil into a 50-ML beaker. Add 20ML of distilled water and allow to stand for 30 minutes and stir occasionally with a glass rod.

ii) Insert the electrodes of the pH meter into the partly settled suspension during measurement.

iii) Report result as "Soil pH measured in Water".

C. Determination of Organic Matter

Organic matter consists of an accumulation of undecomposed or partly decomposed roots, stems and leaves of higher plants and residue of worms, anthropods, bacteria, algae and fungi. The dead remains of these materials added to the soil are converted into dark coloured complexes known as humus (Aduayi, 1985). The humus is slowly oxidized to carbonates, water and nitrates and other sample substances, which serve as food for plants. The soil organic matter is the basic store house of plant nutrient. It provides all the sixteen essential mineral elements and more, and also binds soil particles together allowing for easy exchange of water in the soil (Bernard, 2004). Organic matter is an essential and characteristic constituent of the soil. It exerts a profound influence on almost every facet of the soil. It provides nutrients for plant growth, as well as influences the physical properties of the soil, Walkley and Black method was used, in which the reducing materials (organic carbon) in soil is oxidized by addition of potassium dichromate solution and concentrated sulphuric acid forming chromic acid and gases such as nitrogen dioxide and ammonia. The reaction is exothermic that heat is evolved.

Experimental Procedure involved the following:

i) Weigh 1gm of the oven-dry soil sample and grind it into powder. Then pour into beaker.

ii) Weigh 40gms of potassium dichromate ($K_2C_{r2}0_2$) and make up to 1 litre.

iii) Take 10ML of the prepared solution and add to the grounded soil sample - it oxidizes.

iv) Weigh 140gm of iron sulphate ($Fe\ S0_4$) and acidity 15ML of concentrated sulphuric acid (H_2S0_4) and make up to 1 litre.

v) Then add 15 - 20ML of acidified iron sulphate and digest the sample.

vi) Dilute the distilled water to about 200ML.

vii) Titrate with 0.5N ferrous ammonium sulphate by using 2 - 3 drops of orthophenolthalin until the colour just changes to greenish pink.

viii) A blank titration was carried out using the above procedure minus the soil sample. This is used to correct the reading. Calculation - for organic carbon involved the use of:

$$\frac{M/Fe^{2+}\ (\text{Sample - Blank}) \times 0.1 \times 0.03 \times 100}{\text{1gm of Soil Sample}} \quad \ldots\ldots\ldots \text{(I)}$$

Where:

Sample is the real litre

Value, blank litre value

For organic matter content

For organic carbon x 1.724

D. Determination of Total Nitrogen in Soil

Nitrogen is the element above all others that we associate with growth. It is usually the element that is of primary importance in the determination of crop yield and quality (Kunde, 1995). It is required in comparatively large amount and is likely to be deficient in soil unless the best management practice is used.

Experimental Procedure involved the following:

i. Weigh 5 to 10gms of soil sample containing about 10mg of N in a dry 500 - ML Micro - Kjeldahl flask. Add 20ML of distilled water stir the flask for a few minutes then allow it to stand for 30 minutes.

ii. Add 1 tablet of mercury catalyst and 10gm of K_2S0_4. Then add 30ML of concentrated H_2S0_4 through an automatic pipette.

iii. Heat the flask continuously at a low heat on the digest stand.

iv. Allow the flask to cool and slowly add about 100ML of water to the flask.

v. Carefully transfer the digest into another flask 750 - Ml. Wash the sand residue with 50ML of distilled water four times.

vi. Add 50 -ML H3 B03 indicator solution into a 500 - ML Erlenmeyer flask and place under the condenser of the distillation apparatus.

vii. Attach the 750 - ML kjeldahl flask to the distillation apparatus. 150 ML of 10N NaOH through the distillation flask, and commence distillation.

viii. Keep condenser cool (below 30^0c).

ix. Collect 150 - ML distilled and then stop distillation.

x. Determine the NH4 - N in the distillate by titrating with 0.0.N standard HC1.

xi. Calculate the % N content in soil.

E. Determination of "Available Phosphorus in Soils"

This is an important soil nutrient. All plants require phosphorus in relative large quantities for their growth and development. Phosphorus is involved as a constituent element in many specific compounds making up plant structure. It also plays an important role in the metabolic processes, which enables the plants to develop and complement their natural life circle (Asadu and Nweke, 2001).

Experimental Procedure involved the following:

i. Weigh 1gm of air-dried soil sample into 15ML centrifuge tube and add 7Ml of the extracting solution.

ii. Shake for 1 minute on a mechanical shaker and centrifuge the suspension for 15 minutes.

iii. Pipet 2ML of the clear supernatant into a 20ML test tube.

iv. Add 5ML distilled water and 2ML of ammonium molybdate solution.

v. Mix content properly and add 1Ml of $Sucl_20$ dilute solution and mix again.

vi. After 5 minutes, measure % transmittance on the electrophotometer.

vii. Prepare standard curve within the range of 0 - 1 ppm P.

viii. Plot the optical density (0.0) of standard solution against the ppm P and calculate the content of extractable P in soil.

F. Determination of Bulk Density and Total Porosity.

Bulk density refers to the apparent density of compactness of the soil (Areola, 1992), while total porosity on the other hand is the amount of pores present in the soil expressed as a percentage (Peters, 2001).

Experimental Procedure involved the following:

i) Collect soil samples with a core sampler into a plastic bag, and weigh and record the result.

ii) Then you oven-dry at a temperature of 105^{0c} then you weigh again and again and record the result.

iii) Determine the mass of oven-dry soil by finding the difference between the weight of wet soil and the dry soil, divided by the weight of the dry soil and multiply by 100.

iv) Calculate the volume of the core sampler.

v) Bulk density is then determined by dividing the mass of oven-dry soil by the volume of the core sampler.

vi) Total porosity is determined from bulk density and particle density by using the formula:

$$\text{Total porosity} = \left(1 - \frac{BD}{PD}\right). \ldots\ldots\ldots\ldots\ldots\ldots \text{(II)}$$

Where:

1 = Constant
BD = Bulk density
PD = Particle density

G. Determination of Cation Exchange Capacity and Exchangeable Bases.

This element is worthy of note and it is simply the ability of the soil to hold and exchange cations (calcium, potassium, sodium and magnesium), for the need of the plant. The degree of exchange is dependent on the nature of clay mineralsand level of organic matter in the soil. The uptake of nutrients by the plant is influenced by the exchange reaction between the soil and the root hair of plants (Asadu and Nweke, 2001). Thus when fertilizer is applied to the soil, it dissolves in the soil solution and changes to ionic forms. The ionic forms enter into a complex process of exchanges in the soil and around the roots and finally enter into the plant.

Experimental procedure involved the following:

The approach is a percolation method and consists of first saturating the absorption complex with ammonium ions after qualitative removal by potassium. The cation exchange capacity is mini equivalent per 100gm of soil. The exchangeable bases are potassium ions, calcium ions can be determined using the percolation method described above.

However, potassium, sodium and calcium are determined by flame emission spectrophotometres, in which magnesium ions can be measured either by flame atomic absorption spectrophotometeric method or simply by colorimetric method.

3.6.2 Statistical Analysis

The paired student t-test was adopted for this study. This statistical technique was used to analyse hypothesis I, which states that there is no significant variation in the number of tree species present in deforested and forested area. The study by Benard (2004) on causes and control of deforestation in Nigeria, adopted this statistical technique.

The multiple regression statistical technique was adopted in testing hypothesis II, which states that the soil fertility status is not significantly dependent on deforestation in the area, hypothesis III which states that the yield of yam and cassava in the area is not significantly dependent on soil fertlity and hypothesis IV, which states that the different soil management methods adopted have no significant improvement on the nutrient status of the soil of the area. The analysis of variance (Anova) was used in testing hypothesis V, which states that there is no significant difference in the yield of yam and cassava among the three (3) regions in Delta State. Mesgari and Ranjbar (2003) in their study on analysis and estimation of deforestation using satellite imagery and GIS in Arasbaran in Indian, adopted the multiple regression statistical technique. Ekanade (1999) in his study on the nature of soil properties under mature forest and plantation of exotic trees in tropical rainforest fringe of South Western Nigeria, adopted one way analysis of variance (Anova). The Tukey test analysis, on the other hand, was used to determine where the variation lies, as well as to see wether the differences among yield of crops (yam and cassava) among the three regions are significant or not.

The data were entered in statistical package for social sciences (SPSS) version 15 and double checked before analysis.

3.7 Reliability and Validity of Instrument

To ensure an efficient reliability of the instrument, the test to retest method was used, where ten questionnaires were tested. This is represented by the formulae below:-

$$r = \frac{\sum (x-\bar{x})\ (y-\bar{y})}{\sqrt{\sum (x-x)^2\ (y-y)^2}} \text{......................(III)}$$

Where ∑ = Summation

X = Independent variable

Y = Dependent variable

Three questions were selected from the questionnaires to test if the research questionnaires were reliable to generate and explain vital information on the study.

At 0.98 (98%) the instrument was reliable to generate and explain vital information on the study (Appendix III).

CHAPTER FOUR

PRESENTATION, ANALYSIS OF DATA AND DISCUSION

4.1 Introduction

This chapter discusses the vegetation physiognomy and physico-chemical characteristics of soil under deforested and forested plots. This is with the view of assessing the effects of deforestation on soil fertility.

4.2 Variation in Tree Species in Forested and Deforested Areas.

Table 4.1: Tree Species Loss

Species	Common names	Forested Sites (A)	Deforested Sites (B)	Species loss (A-B)	Species % loss
Anitiaris Africana	False Iroko tree	64	36	28	12.7
Milicia excelsa	Iroko tree	190	98	92	41.8
Pentaclethra macrophylla	Oil bean tree	36	20	16	7.3
Irvingia gabonensis	Bush mango	50	22	28	12.7
Khaya spp.	Mahogany tree	116	60	56	25.5
	Total	456	236	220	100

Source: Field survey, 2011

As indicated in Table 4.1, the listed trees are the dominant tree species ≥ 10m tall that were enumerated and recorded at time of establishment at the sample sites. In table 4.1, the tree lost in both deforested and forested area, with *Milicia excelsa* as the highest and the least tree species lost is the *Irvingia gabonensis.* It also revealed a total of 98 *Milicia excelsa* as against 190 in forested area. This shows that 41.8% of *Milicia excelsa* has been lost to active exploitation. Others showed 25.5%, 7.3%, 12.7% and 12.7% degradation for *Khaya spp.*, *Pentaclethra Macophylla*, *Antiaris Africana* and *Irvingia gabonensis* respectively. The specie found in forested area have been destroyed by man's activities in the degraded forest leading to the high rate of deforestation. Thus, this finding corroborates the study of Geist and Lambin (2003) that anthropogenic factors of deforestation can be categorized broadly as proximate and underlying causes. It reduces the area, quality and quantity of woody vegetation cover and alter the spatial structure of landscape through the process of fragmentation (Noss, 1999 and Fitzsimmons, 2003).

All trees were identified by species and reach height of up to 30-50 metres and attain a girth of 2.8 metres. The *Milicia excelsa* (Iroko tree) is a large deciduous tree with bark thick, pale, ash grey to nearly black, then brown, usually fairly rough and flaking off in small scales, but seldom fissured; slash thick, fibrous, cream cloloured with brown spots, exuding white latex; trunk lofty, straight and cylindrical, up to 20 metres or more to the 1st branches, usually with short blunt buttresses; crown high, umbrella-like and growing from a few thick branches; branchlets thick, rather zigzag and angular, all more or less horizontal (Orwa, C.; Mutua, A.; Kindt, R.; Jamnadass, R and Anthony, S. 2009). While the *Pentaclethra Macrophylla* (oil bean tree) is the sole member of the genus. It is a leguminous tree (family leguminosae, sub-family mimosoideae), and recognized by peasant farmers for its soil improvement properties (Agbogidi, 2010). The tree specie found in forested area consist of tall trees, many of which do not appear to reach maturity before rotting away. This is attributed to extremely poor anaerobic soil conditions (Areola, 1991). While the trees found in deforested areas have been destroyed by man's activities, leading to high rate of deforestation. Thus, the finding corroborates the study of Chidumayo and Kwibisa (2002) that human activities in the form of agricultural practices, lumbering, sand excavation and fuel wood exploitation leads to high rate of deforestation.

Table 4.2: Species Variations in Deforested Sites

Species	A	B	C	D	E	F	G	H	I	J	K	L	Total
Anitiaris Africana	5	3	2	4	3	2	3	4	5	5	3	3	42
Milicia excelsa	10	6	6	5	4	3	3	6	12	4	8	3	70
Pentaclethra macrophylla	2	3	2	2	2	3	4	2	2	2	2	3	29
Irvingia gabonensis	6	3	2	2	3	4	2	2	3	5	4	6	42
Khaya spp.	2	3	2	7	4	3	3	10	5	3	7	4	53
TOTAL	25	18	14	20	16	15	15	24	27	19	24	19	236

The locations are A: Akwukwu-Igbo, B: Ubulu- Ukwu, C: Emu-Uno, D: Okpai, E: Aradhe, F: Oleh, G: Otor-Owhe, H: Ubeji, I: Agbarho, J: Oghara, K: Otor-Udu and L: Ewvreni Communities. Source:
Field Survey, 2011

Table 4.2 shows tree species distribution in deforested area of Delta State. The dominant tree species available in deforested area is the *milicia excelsa* (Iroko tree) and the least tree specie available is the *Pentaclethra Macrophylla (*Oil bean tree). It also revealed that more variety of tree species are found in Agbarho while very few varieties of species are found in Emu-Uno. These variations are as a result of anthropogenic activities in the areas (Geist and Lambin, 2003).

Table 4.3 Species Variation in Forested Sites.

Species	A	B	C	D	E	F	G	H	I	J	K	L	Total
Anitiaris Africana	10	6	4	6	4	6	5	5	9	8	6	8	77
Milicia excelsa	13	12	14	16	21	12	9	12	3	8	12	10	142
Pentaclethra macrophylla	7	8	4	6	3	4	4	3	7	3	3	5	57
Irvingia gabonensis	9	8	6	4	5	5	4	3	5	4	3	4	60
Khaya spp.	6	8	9	14	9	10	9	12	12	10	12	9	120
TOTAL	45	42	37	46	42	37	31	35	36	33	36	36	456

The locations are A: Akwukwu-Igbo, B: Ubulu- Ukwu, C: Emu-Uno, D: Okpai, E: Aradhe, F: Oleh, G: Otor-Owhe, H: Ubeji, I: Agbarho, J: Oghara, K: Otor-Udu and L: Ewvreni.
Source: Field Survey, 2011

Table 4.3 shows tree species distribution in forested area of Delta State. The dominant tree species available in the forested area of Delta State is the *Milicia excelsa* (Iroko tree) and the least tree specie available is the *pentaclethra macrophylla* (oil bean tree). It also revealed that more variety of tree species are found in Okpai while very few varieties of species are found in Otor-Owhe.

Table 4.4 Deforestation Rate in Delta State

Study sites	No of trees available in deforested area	No of trees available in forested area	Total number of trees in both deforested and forested area	% of available trees
Akwukwu-Igbo	17	33	50	7.2
Ubulu-Ukwu	19	45	64	9.2
Emu-Uno	26	24	50	7.2
Okpai	32	47	78	11.3
Aradhe	15	43	58	8.4
Oleh	24	47	71	10.3
Otor-Owhe	16	44	60	8.7
Ubeji	16	28	44	6.4
Agbarho	18	41	59	8.5
Oghara	17	39	56	8.1
Otor-Udu	20	35	55	7.9
Evwreni	16	31	47	6.8
Total	236	456	692	100

Source: Filed Survey, 2011

Table 4.4 shows the number of available trees in both deforested and forested area in Delta State . However, the number of trees per quadrant found in the entire deforested area is lesser than those of the forested area and this is evidence from 236 trees and 456 trees observed in both degraded and forested area. Ubeji has a lesser percentage of 6.4% of the trees available in both deforested and forested area, while Okpai has the highest percentage of 11.3% of the trees available in both deforested and forested area. This variation in tree species between deforested and forested area could be attributed to agricultural practices, infrastructural development, bush fire, lumbering and fuelwood exploitation in the area. This observation is in line with the finding of (Areola, 1991). Thus, the deforestation is attributed to an increase urbanization process and this finding corroborates with the works of Ojima et al, (1994) and Lambin et al, (2003) that wood extraction, agricultural expansion, urbanization and infrastructure development are proximate cause of deforestation. It reduce the area, quality and quantity of woody vegetation cover and alter the spatial structure of landscapes through the process of fragmentation which is also related to deforestation and loss of forest cover (Noss, 1999 and Fitzsimmons, 2003).

Table 4.5 Comperative Study of Scholars Results on Vegetation Loss.

Authors/year	Title/place	Locations	Vegetation Loss %
Bernard, (2004) *	The causes and control of deforestation in forest zone of Nigeria	Site A Site B Site C Site D Site E	21.8 18.4 16.2 18.9 12.6
Onokerhoraye and Omuta, (2005) **	Perspectives on Development in Nigeria	Afiesere Ofuoma Eruemukohwaren Ekapkpamre Orogun	22.6 16.3 8.1 2.4 23.7

Author's field survey (2011) ****	Effects of deforestation on soil fertility of Delta State, Nigeria.	Akwukwu-Igbo Ubulu-Ukwu Emu-Uno Okpai Aradhe Oleh Otor-Owhe Ubeji Agbarho Oghara Udu Ewvreni	7.2 9.2 7.2 11.3 8.4 10.0 8.7 6.4 8.4 8.5 7.9 6.8

Source: *Bernard (2004)

** Onokerhoraye and Omuta (2005)

*** Ogadi (2006)

**** Author's field work (2011).

As indicated in Table 4.5, studies by Bernard (2004) was carried out in River State of Nigeria, Onokerhoraye and Omuta (2005) in Delta Central, Nigeria, Ogadi (2006) in Enugu, Eastern area of Nigeria and author's field survey (2011) was in Delta State, Nigeria. The various studies noted loss in vegetation in the various study sites, but the loss in vegetation in Delta State is lower than that of Rivers State (Table 4.5). The loss in vegetation could be attributed to wood extraction, population pressure as a result of urbanization and infrastructural development are proximate causes of deforestation (Lambin et al, 2003). As indicated in Table 4.5, the author's result is in line with the findings of previous scholars on vegetation loss as a result of deforestation.

The available trees in forested and deforested area in Delta State is 692. However, the number of trees per quadrant found in the entire deforested area is 236, while 456 trees were seen in forested area. Delta North region has 242 trees, Delta Central 233 trees and Delta South 217 trees. Delta North has the lowest forest depletion of 34.9%, followed by Delta Central with 33.5% and Delta South with 31.6%. This is as a result of human anthropogenic activities of agricultural practices, lumbering, sand escarvation and fuelwood exploitation in the area.

4.3 Causes of Deforestation in Delta State

Table 4.6 Percived Causes of Deforestation.

Causes of deforestation	Scale of Severity							
	1	%	2	%	3	%	4	%
Farming	123	14.6	-	-	3.53	37.2	4.24	48.2
Population pressure	-	-	160	19	196	23.4	554	57.6
Infrastructure development	684	70.1	216	29.9	-	-	-	47
Lumbering	57	6.4	221	22.4	-	-	622	40.7
Fuel wood	165	20	-	-	312	33	423	30.5

Where 5-very high, 4- high, 3 –moderate, 2-low, 1-extremenly low.
Source: field survey 2011

Table 4.6 shows the order of severiety on causes of deforestation According to the expression of the inhabitants on causes of deforestation, population pressure accounted for 57.6% as the major causes of deforestation and 30.5% of the respondents sees fuel wood as the least of causes of deforestation. This is in line with the view of Lambin, (2003) who posited that wood extraction, population pressure as a result of urbanization and infrastructural development are proximate causes of deforestation. Other causes of deforestation are farming, which accounted for 48.2% , lumbering, which accounted for 40.7% and infrastructural development, which accounted for 47%.

Table 4.7 Cooking Fuel Types.

Cooking fuel	No. of Respondents	%
Firewood	497	41.4
Charcoal	96	8
Kerosene	282	23.5
Gas	91	7.6
Sawdust	234	19.5
Total	1,200	100

Source: Field Survey, 2011

From Table 4.7, 41.4% of the respondents use firewood as a source of cooking fuel while about 7% uses gas as their source of cooking fuel. Thus firewood is the dominant source of cooking fuel and this is gotten from trees that are exploited from the forest. Wood extraction is a proximate cause of deforestation (Lambin et al, 2003) and this finding corroborates with the work of Oke and Oyun (1997) and Panter (2009).

4.3.1 Test of Hypothesis One.

Test of hypothesis one. The hypothesis states that there is no significant variation in the number of trees species present in deforested and forested sites in Delta State. The data for the paired t-test analysis of the hypothesis is found in Appendix II.

Table 4.8 Paired Sample Statistics.

	Mean	N	Std. Deviation	Std. error mean
Pair Forested 1 Deforested	34.61 17.92	12 12	5.329 7.316	1.863 2.584

From table 4.8, the mean value of the forested site was 34.61 (SD =5.329) and the mean of the deforested site after man's anthropogenic activities, was 17.92 (SD = 7.316), indicating that there is more variation in tree species in the deforested area than the forested area.

Table 4.9 Paired Sample Statistics

Paired Differences								
	Mean	Std. Deviation	Std. error	95% confidence interval of the difference		t	df	Sig. (2-tailed)
				Lower	Upper			
Pair 1 Forested-Deforested	17.423	7.423	2.534	9.896	22.51	7.642	8	0.001

Table 4.9 shows that the calculated t value of 7.642 is greater than the critical table value of 2.843 at $P< 0.05$ and thus, the model is significant. Therefore, the null hypothesis was rejected and the alternative hypothesis accepted, which state that there is a significant variation in the number of trees species present in forested and deforested sites in the twelve locations in Delta State.

This result signifies that anthropogenic activities of uncontrolled logging, sand excarvation, fuelwood exploitation and bush firing are responsible for loss of tree species in Delta State.

4.4 Physico-Chemical Properties of Soil

This section examines the physico-chemical properties of soils under deforested and forested plots.

Table 4.10 Mean Annual Physico-Chemical Properties of Soil under Forested and Deforested Plots in Delta State.

	Forested		Deforested		Loss
Soil properties	Range	$\bar{X}$	Range	$\bar{X}$	
Sand %	92.8 – 83.4 ±	90.3	97.2 - 69.12 ±	88.6	1.7

Silt %	9.2 - 2.6 ± 4.6	13.2 - 2.6 ± 5.9	1.3
Clay %	9.9 - 2.8 ± 5.5	10.3 - 2.1 ± 5.1	0.4
Bulk Density	1.44 - 1.17 ± 1.31	1.89 - 0.73 ± 1.34	0.03
Total Porosity %	65.88 - 62. ± 68.2	70.5 - 49.33 ± 60.2	8
Soil pH (in water)	5.67 - 5.01 ± 5.3	5.84 - 4.06 ± 4.9	0.4
Organic Carbon %	6.24 - 1.84 ± 4.4	4.81 - 0.22 ± 3.3	1.1
Total Nitrogen %	0.94 - 0.19 ± 0.43	0.70 - 0.05 ± 0.34	.09
Available Phos.	11.54 – 7.6 ± 8.6	7.72 - 1.21 ± 5.4	3.2
CEC	4.08 - 2.72 ± 3.98	6.3 - 0.33 ± 2.77	1.2
Magnesium	3.11 - 2.0 ± 2.21	3.78 - 0.78 ± 2.53	0.3
Potassium	0.67 - 0.31 ± 0.42	0.42 - 0.05 ± 0.17	0.25
Sodium	0.41 - 0.0 ± 0.16	0.47 - 0.01 ± 0.19	0.03
Calcium	1.51 - 0.1 ± 0.56	0.99 - 0.01 ± 0.26	0.3

Source: Field Survey, 2011

As indicated in Table 4.10, the total mean values of sand, silt and clay are 88.9%, 5.9% and 5.1% respectively for deforested plots, while that of forested area are 90.3%, 4.59% and 5.53% for sand, silt and clay respectively. This distribution shows that soils under forested and deforested plots are predominantly sandy, and texturally homogeneous since the differences in mean values of forested and deforested areas is not much. This is to be expected since the soils are derived from the same parent material. This result is in line with the findings of (Asadu; Ezeaku and Nnaji 2004) in their study on soils of sub-saharan Africa and the management needs for sustainable farming in Nigeria, posited that vast majority of soils from the same parent material are predominantely sandy and texturally homogeneous. The sandy nature of the vast majority of the soils is also responsible for their rapid internal drainage and relatively high susceptibility to drought when the vegetative cover is removed.

The total mean values for bulk density and total porosity are 1.34 and 60.2% respectively, while that of forested area are 1.31 and 68.2% respectively. Thus, this result corroborates the findings of Ekanade (1999) on the nature of soil properties under mature forest and plantains of fruiting and exotic trees in tropical rain forest in Nigeria and Chidumayo and Kwibisa (2002) on effects of deforestation on grass biomass and soil nutrient status in Miombo woodland in Zambia, posited that the modification of some forest soils structural properties is as a result of its higher organic matter content. While the higher total porosity value obtained in forested area, could be attributed to improvement of forest soil structure, which may be due to its higher organic carbon contents (OC). The lower total porosity value obtained in deforested plots could be as a result of greater structural degradation in deforested soils. This result indicates that soils under forested area have a better physical status than those of deforested plots; because they are less compact and more porous. Areola (1991) and Alakin (2009) pointed out that this might be due to the fact that the forested area which is multi layered is able to protect the soil against direct solar radiation and the direct impact of rain drops than the deforested plots which are single layered. The total mean values for soil pH, organic carbon and total nitrogen are 4.86, 3.3% and o.34% respectively for deforested plots, while that of forested area are 5.29, 4.42% and 0.43% respectively. The lower value of pH observed in deforested plots, suggests that the cultivation of the major crops of yam and cassava in the area, make a great demand on soil nutrients such as calcium and magnesium. Moreso, the loss of soil bases in the soil through leaching or uptake by plants, result in soil acidity. This result is in line with the finding of Bongfen (2002) on the characteristics of soils under permanent and shifting cultivation in Kinshasha area of Zaire. While the high mean value observed in forested area could be attributed to occasional burning of the forested plots. This is because the release of bases during burning raises pH of acid soils nearer the neutral points. This result corroborates the findings of (Oya, K.; Tokashiki, Y and Shimo, M. 1995) on changes in physical and chemical properties of soils in Japan, and Daubenmire (2007) on plants and environment in India.

The total mean values for available phosphorus and cation exchange capacity are (5.4) and (2.53) respectively, while that of forested area are (8.63) and (3.98) respectively. This distribution shows a variation in both deforested and forested area. This variation may be due to the fact that the cultivated crops of yam and cassava in the deforested plots absorbs more of this nutrients from the soil. This finding is in line with the observation by Ekanade (1999) and Nnaji, (2002).

And the total mean values for magnesium, potassium, sodium and calcium are (2.53), (0.17), (0.19) and (0.26) respectively, while that of forested area are (2.21), (0.42), (0.16) and (0.56) respectively. This variation could be attributed to the continuous and permanent use of the soil of the area for the growth of crops. Most of the soils synthesis in the plant growth is usually very high when compared with the forested plots where cultivation do not take place. This result is in line with the finding of Aikore et al, (2003) on soil quality decline in response to long term continuous cultivation and management practice in Nigeria. In terms of potassium, the variation can be attributed to the fact that in continuous and permanent cultivated plots, the available potassium have been continuously absorbed without applying any soil management techniques that will help improve the soil. Most of the crops make use of it for their maturation and uptake of other elements. Since the area is widely exposed to climatic activities, there is need for its immediate absorption when compared with the forested plots. This finding is in line with the findings of Kunde (1995) on the characteristics of soils under permanent and shifting cultivation in Zambia, and Bernard (2004) on the causes and control of deforestation in forest zone in Nigeria.

In terms of sodium, the distribution shows a variation in both deforested and forested area. This variation could be attributed to leaching and high rate of sodium absorption by plots that have low sodium content. This finding corroborates those of Lal (2000) and (Alegre.; Carsel. and Mkarim. 2004). This variation could be attributed to the previously available calcium absorbed by plants each year. Calcium support activities of soil organization, but since the soil organization content is not much, due to the effect of continuous and permanent cultivation in the area, the calcium content tend to decline while that of forested plots is higher having (0.56) which is as a result of soil organism in the plots not exposed to direct sunlight and continuous cropping. Hence it increases the calcium of the area due to decomposition. This result is in line with the findings of (Oya; Tokashiki and Shimo 1995) on changes in physical and chemical properties of soils in Japan, and Ifende (2010) on tropical rainforest resources in Nigeria.

Table 4.11 shows the range and mean values of physico-chemical properties of soil under forested and deforested plots in Delta State.

4.4.1 Particle Size Composition.

This refers to the relative proportions of sand, silt and clay in the soil. It influences not only the structure, consistence and stability of the soil, but also the ability of the soil to hold and exchange nutrients. It also determines soil response to fertilizer application in agricultural lands (Bongfen, 2002).

As indicated in Table 4.11, the mean values of sand, silt and clay are 90.1%, 5.3% and 4.0% for Akwukwu-Igbo, 89.4%, 4.7% and 4.6% for Ubulu-Ukwu, 88.8%, 4.9% and 4.1% for Emu-Uno, 88.1%, 4.8% and 4.8% for Okpai, 88.4%, 3.7% and 5.4 for Aradhe, 87.1%, 5.5% and 6.7% for Oleh, 88.4%, 5.9% and 5.9% for Otor-Owhe, 84.1%, 10.2% and 5.4% for Ubeji, 91.1%, 7.0% and 3.0% for Agbarho, 89.5%, 4.7% and 4.8% for Oghara, 87.5%, 5.9% and 8.2% for Udu and 90.9%, 5.1% and 2.8% for Ewvreni, while that of forested area are 90.3%, 4.59% and 4.59% for sand, silt and clay respectively. This distribution indicates that Akwukwu-Igbo has the highest value of 91.1% and Ubeji with the lowest value of 84.1% of sand and Ubeji has the highest value of 10.2% and Arahde has the lowest value of 3.7% of silt and Emu-Uno has the highest value of 8.2% and Akwukwu-Igbo with the lowest value of 3.0% of clay. This distribution shows that soils under forested and deforested plots are predominantly sandy, and texturally homogeneous since the differences in mean values of forested and deforested area is not much. This is to be expected since the soils are derived from the same parent material. This result is in line with the findings of (Asadu, C.L.A. and Nweke, F.I. 2001) in their study on soils of sub-saharan Africa and the management needs for sustainable farming in Nigeria, posited that vast majority of soils from the same parent material are predominantely sandy and texturally homogeneous. The sandy nature of the vast majority of the soils is also responsible for their rapid internal drainage and relatively high susceptibility to drought when the vegetative cover is removed. The mean values of sand, silt and clay in the different locations in the study area is represented in Figure 4.1, 4.2 and 4.3 respectivvely.

4.4.2 Bulk Density and Total Porosity.

Bulk density refers to the apparent density of compactness of the soil (Bongfen, 2002), while total porosity on the other hand is the amount of pores present in the soil expressed in percentage (Okpor, 2008).

As indicated in Table 4.11, the mean values of bulk density and total porosity are 1.4 and 59.5% for Akwukwu-Igbo, 1.3 and 63.2% for Ubulu-Ukwu, 1.3 and 61.3% for Emu-Uno, 1.3 and 60.4% for Okpai, 1.3 and 62.33% for Aradhe, 1.2 and 60.9% for Oleh, 1.2 and 58.7% for Otor-Owhe, 1.3 and 59.2% for Ubeji,1.4 and 53.3% for Agbarho, 1.5 and 62.5% for Oghara, 1.4 and 61.2% for Udu and 1.3 and 64.4% for Ewvreni, while that of forested area are 1.31 and 68.2% for bulk density and total porosity respectively. This distribution indicates that Agbrho and Akwukwu-Igbo has the highest value of 1.4 and Oleh and Otor-Owhe with the lowest value of 1.2 of bulk density. While Evwreni has the highest value of 64.4% and Agbarho with the lowest value of 53.3% of total porosity. Conversely, as indicated in Table 4.11, the value obtained for bulk density is lower, when compared with the values obtained from deforested plots. The lower value of bulk density obtained in soils of forested area may be attributed to the modification of some forest soils structural properties by its higher organic matter content. Thus, this result corroborates the findings of Ekanade (1999) on the nature of soil properties under mature forest and plantains of fruiting and exotic trees in tropical rain forest in Nigeria and Chidumayo and Kwibisa (2002) on effects of deforestation on grass biomass and soil nutrient status in Miombo woodland in Zambia, posited that the modification of some forest soils structural properties is as a result of its higher organic matter content. While the higher total porosity value obtained in forested area, could be attributed to improvement of forest soil structure, which may be due to its higher organic carbon contents (OC). The lower total porosity value obtained in deforested plots could be as a result of greater structural degradation in deforested soils. This result indicates that soils under forested area have a better physical status than those of deforested plots; because they are less compact and more porous. Areola (1991) and Alakin (2009) pointed out that this might be due to the fact that the forested area which is multi layered is able to protect the soil against direst solar radiation and the direct impact of rain drops than the deforested plots which are single layered. The implication of a reduction in porosity in deforested plots is that permeability will decrease; hence surface run-off and soil erosion will increase appreciably, leading to further loss of soil nutrients and deterioration in soil physical status. This finding corroborates those of (Areola, 1991 and Angelsen and Kaimowitz, 2010). The mean values of bulk density and total porosity in different locations in the study area is represented in Figures 4.4 and 4.5 respectively.

Thus, the result signifies that the higher content of bulk density observed in deforested plot will affect the modification of some forest soils structural properties by its higher organic matter content. Also the lower content of total prorosity observed in deforested plots, implies a structural degradation in soils.

4.4.3 Soil pH

This is a measure of hydrogen ion concentration in the soil (Badejo, et al, 1999). Soil pH is generally regarded as a very important soil property because it controls the amount of nutrients available to plants. It tends to correlate with other soil properties such as the base saturation. The soil pH may either be acidic or alkaline. There are two ions that are responsible for the state of pH of the soil. They are hydrogen ions (H+) and the hydroxyl ions (H-). When the concentration of hydrogen ions is greater than the hydroxyl ions, such a soil is referred to as being acidic and when the reverse occurs, the soil is referred to as alkaline. On the other hand, when the level of hydrogen ions is equal to that of hydroxyl ions, the soil is referred to as being neutral (Aduayi, 1985).

As indicated in Table 4.11, the mean values of soil pH are 4.9 for Akwukwu-Igbo, 4.8 for Ubulu-Ukwu, 4.8 for Emu-Uno, 4.8 for Okpai, 5.2 for Aradhe, 4.9 for Oleh, 5.2 for Otor-Owhe, 4.9 for Ubeji, 5.0 for Agbarho, 4.6 for Oghara, 4.0 for Otor-Udu and 4.9 for Ewvreni, while that of forested plot is 5.29. This distribution indicates that Aradhe and Otor-Owhe has the highest value of 5.2 and Otor-Udu with the lowest value of 4.0 of soil pH. The lower value of pH observed in deforested plots, suggests that the cultivation of the major crops of yam and cassava in the area, make a great demand on soil nutrients such as calcium and magnesium. Moreso, the loss of soil bases in the soil through leaching or uptake by plants, result in soil acidity. This result is in line with the finding of Bongfen (2002) on the characteristics of soils under permanent and shifting cultivation in Kinshasha area of Zaire. Thus the high mean value observed in forested area could be attributed to occasional burning of the forested plots. This is because the release of bases during burning raises pH of acid soils nearer the neutral points. This result corroborates the findings of (Oya; Tokashiki and Shimo 1995) on changes in physical and chemical properties of soils in Japan, and Daubenmire (2007) on plants and environment in India.

It's obvious that both soils of forested and deforested in Delta State are acidic because they are within 4 to 5 values (Table 4.11). The acidity of the soil may be attributed to a heavy annual rainfall resulting in depletion of the cations. Also the soils of the study area are sandy. Sandy soils are from quartz, and they have low cation exchange capacity. This result corroborates the finding of Asadu and Nweke (2001) on soils of Arable crop fields in sub-saharan Africa in Nigeria, the mean values of soil pH in the different locations in the study area is represented in Figure 4.6. Moreso, the spatial distribution of pH in the study area is represented in Figure 4.7.

The obtained result signifies that the lower content of soil pH observed in deforested plots, implies a reduction in soil fertility as a result of great demand made by crops in the process of nutrient up take in deforested plots.

4.4.4 Organic Carbon.

Organic matter consists of an accumulation of undecomposed or partly decomposed roots, stems and leaves of higher plants, and residue of worms, arthropods, bacteria, algae and fungi. The dead remains of these materials added to the soil are converted into dark coloured complexes known as humus (Asadu, 1999). The humus is slowly oxidized to carbonates, water and nitrates and offer simple substances, which serves as food for plants. The soil organic matter is the basic store-house of plant nutrient. It provides all the sixteen essential mineral elements and more, and also binds soil particles together allowing for easy exchange of water in the soil (Asadu, 1999).

Organic matter is an essential characteristic constituent of the soil. It exerts a profound influence on almost every facet of the soil. It provides nutrients for plant growth, as well as influences the physical properties of the soil.

As indicated in Table 4.11 the mean values of organic carbon are 1.0% for Akwukwu-Igbo, 1.8% for Ubulu-Ukwu, 2.6% for Emu-Uno, 2.8% for Okpai, 1.9% for Aradhe, 1.1% for Oleh, 4.2% for Otor-Owhe, 3.6% for Ubeji, 4.3% for Agbarho, 4.2% for Oghara, 1.5% for Udu and 4.0% for Ewvreni, while that of forested area is 4.42% for organic carbon. This distribution indicates that Agbarho has the highest value of 4.3% and

Akwukwu-Igbo with the lowest value of 1.0% of organic carbon. This distribution shows a variation in both deforested and forested area. Their variation can be attributed to the possible higher rate of litter production under forested soils than those of deforested plots. This result is in line with the finding of Alakin (2009) on landuse and soil management situation in Nigeria. The higher foliage cover and vegetation biomass of forest would support a higher rate of organic matter production (Chidumayo and Kwibisa 2002). The greater cover of the forested plots could have made much impact with regards to addition of most organic matter to the soil but due to the occasional burning of the forested plots during the dry season. This has reduced the organic carbon content. Organic matter accumulates more in the first 20cm of the surface soil. And it is conventional to aim at soil organic matter of between 1.5 to 5% to maintain soil fertility (Vine, 2003 and Okpor, 2008). The mean values of organic carbon in different locations in the study area is represented in Figure 4.8. The spatial distribution of organic carbon in the study area is represented in Figure 4.9.

Thus, the observed result signifies that a reduction in organic carbon content in deforested plots implies a reduction in the essential characteristics constituent of the soil, as well as the physical properties of the soil. Since organic carbon provide nutrients for plant growth, the reduction observed in organic carbon content in deforested plots of Delta State, will affect the yield of yam and cassava in the area.

4.4.5 Total Nitrogen

Nitrogen is the element above all others that we associate with growth. It is usually the element that is of primary importance in the determination of crop yields and quality (Okpor, 2008). It is required in comparatively large amount and is likely to be deficient in soil when the best management practices are not adopted.

As indicated in Table 4.11, the mean values of total nitrogen are 0.1 for Akwukwu-Igbo, 0.3% for Ubulu-Ukwu, 0.2% for Emu-Uno, 0.2% for Okpai, 0.36% for Aradhe, 0.2% for Oleh. 0.6% for Otor-Owhe, 0.4% for Ubeji, 0.49% for Agbarho, 0.48% for Oghara, 0.15% for Udu and 0.33% for Ewvreni while that of forested area is 0.43% for total nitrogen. This distribution indicates that Agbarho has the highest value of 0.49 and Akwukwu-Igbo with the lowest value of 0.1% of total nitrogen. This distribution shows a variation in both deforested and forested area. This variation in total nitrogen content could be attributed to the fact that forested plots consist of varied leguminous plant species that are known to fix nitrogen, thereby enhancing the build-up of nitrogen components in the soil. This finding corroborates those of (Terborgh, 1992 and Gilman, 2006). Also the level of organic matter has been indicated to be higher under forested area than those under deforested plots. Since organic matter is a major source and store house of nitrogen components, therefore nitrogen respond to the level of organic matter content in the soil. This result is in line with the finding of Lal (2000) on the effect of fallow and continuous cultivation on chemical and physical properties of an alfisol in the tropics in Nigeria. The mean values of total nitrogen in the different locations in the study area is represented in Figure 4.10.

The obtained result signifies that the lower content of total nitrogen observed in deforested plots, implies the absence of leguminous plant species in deforested plots, that fix nitrogen in the soil that enhances fertility.

4.4.6 Available Phosphorus.

This is an important soil nutrient. All plants requires phosphorus in relative large quantities for their growth and development. Phosphorus is involved as a constituent element in many specific compounds making up the plant structure. It also plays an important role in the metabolic processes, which enable the plants to develop and complete their natural life cycle.

As indicated in Table 4.11, the mean values of available phosphorus are (3.4) for Akwukwu-Igbo, (4.3) for Ubulu-Ukwu, (4.8) for Emu-Uno, (4.9) for Okpai, (7.1) for Aradhe, (7.1) for Oleh, (3.4) for Otor-Owhe, (2.9) for Ubeji and (6.9) for Agbarho, (5.4) for Oghara, (5.6) for Udu and (6.8) for Ewvreni, while that of forested area is (8.63) for available phosphorus. This distribution indicates that Aradhe and Oleh has the highest value of (7.1) and Ubeji with the lowest value of (2.9) of available phosphorus. This distribution shows a variation in both deforested and forested area. This variation may be due to the fact that the cultivated crops of yam and cassava in the deforested plots absorbs more of this nutrients from the soil. This finding is in line with the observation by Ekanade (1999). The mean values of available phosphorus in the different locations in the study area is represented in Figure 4.11.

Thus, the result signifies that the lower content of the available phosporus observed in deforested plots, implies a reduction in soil fertility level following the cultivation of yam and cassava in the area, which absorbs more of the nutrients from the soil.

4.4.7 Cations Exchange Capacity.

This element is worthy of note and it is simply the ability of the soil to hold and exchange cations (K, Mg, Na, H) for the need of the plant. The degree of exchange is dependent on the nature of clay minerals and level of organic matter in the soil. The uptake of nutrients by the plant is influenced by the exchange reaction between the soil and the root hair of plants. Thus when a fertilizer is applied to the soil, it dissolves in the soil solution and changes to ionic forms. The ionic forms enter into a complex process of exchanges in the soil and around the roots and finally enter into the plant (Gilman, 2006).

As shown in Table 4.11, the mean values of cation exchange capacity (CEC) are (2.5) for Akwukwu-Igbo, (2.7) for Ubulu-Ukwu, (2.7) for Emu-Uno, (2.8) for Okpai, (2.9) for Aradhe, (2.2) for Oleh, (2.3) for Otor-Owhe, (2.4) for Ubeji, (3.1) for Agbarho, (3.7) for Oghara, (2.8) for Udu and (3.3) for Ewvreni, while that of forested area is (3.98) for cation exchange capacity.

This distribution indicates that Oghara has the highest values of (3.7) and Oleh with the lowest value of (2.2). This distribution shows a variation in both deforested and forested area. The mean values of cation exchange capacity in the different locations in the study area is represented in Figure 4.12, and the spatial distribution of cation exchange capacity in the region is represented in Figure 4.13.

The obtained result signifies that the lower content of cation exchange capacity observed in deforested plots, implies a reduction in the exchange reaction in the up take of nutrients by crops.

4.4.8 Exchangeable Bases (Calcium, Potassium, Sodium and Magnesium). Magnessium

As indicated in Table 4.11, the mean values of magnesium are (1.5) for Akwukwu-Igbo, (2.2) for Ubulu-Ukwu, (2.7) for Emu-Uno, (2.8) for Okpai, (3.3) for Aradhe, (3.1) for Oleh, (1.4) for Otor-Owhe, (1.6) for Ubeji, (3.2) for Agbarho, (2.9) for Oghara, (2.3) for Udu and (3.1) for Ewvreni, while that of forested is (2.21). This distribution indicates that Aradhe has the highest value of (3.3) and Otor-Owhe with the lowest value of (1.4) of magnesium. This distribution shows a variation in both deforested and forested area. The variation could be attributed to the continuous and permanent use of the soil of the area for the growth of crops. Most of the soils synthesis in the plant growth is usually very high when compared with the forested plots where cultivation do not take place. This result is in line with the finding of (Aikore; Oluwatosin; Jaiyeola and Awolola 2003) on soil quality decline in response to long term continuous cultivation and management practice in Nigeria. The mean values of magnessium in the different locations in the study area is represented in Figure 4.14.

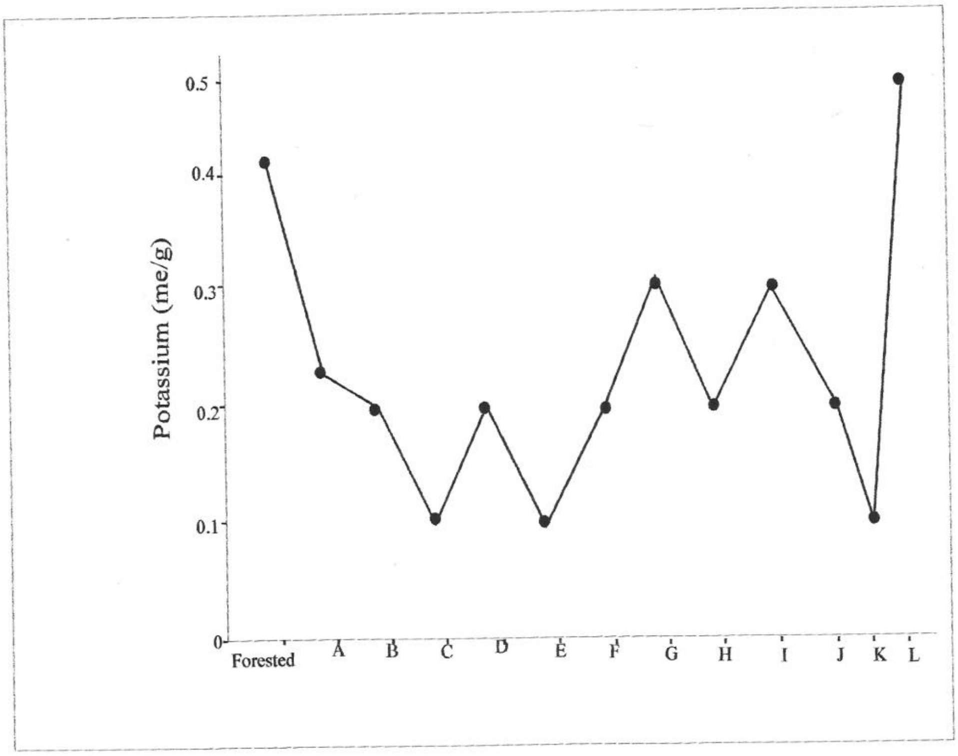
Thus, the result signifies that the lower content of magnesium observed in deforested plots, implies an improved fertility following high soil synthesis in crops grown in deforested plots.

Potassium

As indicated in Table 4.11, the mean values of potassium are (0.3) for Akwukwu-Igbo, (0.2) for Ubulu-Ukwu, (0.1) for Emu-Uno, (0.5) for Okpai, (0.12) for Aradhe, (0.2) for Oleh, (0.3) for Otor-Owhe, (0.2) for Ubeji, (0.25) for Agbarho, (0.15) for Oghara, (0.12) for Udu and (0.16) for Ewvreni, while that of forested is (0.42). This distribution indicates that Okpai has the highest value of (0.5), Emu-Uno with the lowest value of (0.1) of potassium. This distribution shows a variation in both deforested and forested area. The variation can be attributed to the fact that in continuous and permanent cultivated plots, the available potassium have been continuously absorbed without applying any soil management techniques that will help improve the soil. Most of the crops make use of it for their maturation and uptake of other elements. Since the area is

widely exposed to climatic activities, there is need for its immediate absorption when compared with the forested plots. This finding is in line with the findings of Kunde (1995) on the characteristics of soils under permanent and shifting cultivation in Zambia, and Bernard (2004) on the causes and control of deforestation in forest zone in Nigeria. The mean values of potassium in the different locations in the study area is represented in figure 4.15..

The obtained result signifies that the lower content of potassium observed in deforested plots, implies a reduction in soil fertility following continuous and permanent cultivation practiced in the area.



Sodium

As indicated in Table 4.11, the mean values of sodium are (0.3) for Akwukwu-Igbo, (0.2) for Ubulu-Ukwu, (0.2) for Emu-Uno, (0.2) for Okpai, (0.28) for Aradhe, (0.2) for Oleh, (0.2) for Otor-Owhe, (0.11) for Ubeji (0.16) for Agbarho, (0.14) for Oghara, (0.10) for Udu and (0.24) for Ewvreni, while that of the forested is (0.16). This distribution indicates that Akwukwu-Igbo has the highest value of (0.3), Otor Udu with the lowest value of (0.1) of sodium. This distribution shows a variation in both deforested and forested area. The variation could be attributed to leaching and high rate of sodium absorption by plots that have low sodium content. This finding corroborates those of Lal (2000) and (Alegre; Carsel and Makaeim 2004). The mean values of sodium in the different locations in the study area is represented in Figure 4.16..

Thus, the result signifies that the higher content of sodium observed in deforested plots, implies an improved soil fertility as a result of leaching and high absorption rate of sodium by plots that have low sodium content.

Calcium

As indicated in Table 4.11 the mean values of calcium are (0.2) for Akwukwu-Igbo, (0.2) for Ubulu-Ukwu, (0.2) for Emu-Uno, (0.2) for Okpai, (0.56) for Aradhe, (0.2) for Oleh, (0.1) for Otor-Owhe, (0.2) for Ubeji, (0.19) for Agbarho, (0.14) for Oghara, (0.18) for Udu and (0.36) for Ewvreni, while that of deforested is (0.56). This distribution indicates that Aradhe has the highest value of (0.56) and Otor-Owhe with the lowest value of (0.1) of calcium. This distribution shows a variation in both deforested and forested area. The variation could be attributed to the previously available calcium absorbed by plants each year. Calcium support activities of soil organization, but since the soil organization content is not much, due to the effect of continuous and permanent cultivation in the area, the calcium content tend to decline while that of forested plots is higher having (0.56) which is as a result of soil organism in the plots not exposed to direct sunlight and continuous cropping. Hence it increases the calcium of the area due to decomposition. This result is in line with the findings of Oya et al (1995) on changes in physical and chemical properties of soils in Japan, and Ifende (2010) on tropical rainforest resources in Nigeria. The mean values of calcium in the different locations in the study area is represented in Figure 4.17..

The result signifies that the lower content of calcium observed in deforested plots, implies a reduction in soil fertility, following continuous and permananet system of cultivation practiced in the area, affects calcium content in the soil.

Table 4.12 Comparative Study of Scholars Results on Deforestation and Soils.

Authors/Year	Title/Place	Results of cultivated plots	Results of uncultivated plots
Oya et al, (1995) *	Changes in physical and chemical properties of soil in the reclaimed land and forest of Iriomote Island in Japan	pH – 4.68 OC – 1.5 N – 0.17 Av.p – 5.55 Mg – 2.47 K - 0.15	pH – 5.21 OC – 3.65 N – 0.36 Av.p – 8.94 Mg – 2.89 K – 0.47

Chidumayo and Kwibisa, (2002) **	Effects of Deforestation on grass biomass and soil nutrient status in Miombo Woodland in Zambia	pH – 3.62 OC – 1.8 N – 0.4 Av.p – 1.08 Mg – 1.18 K – 0.17	pH – 4.68 OC – 2.5 N – 0.9 Av.p – 2.03 Mg – 1.91 K – 0.36
Ezeaku, (2002) ***	The soils of sub-saharan Africa and Management need for Sustainable farming	pH – 4.3 OC – 1.54 N – 0.18 Av.p – 5.23 Mg – 2.13 K – 0.11	pH – 4.9 OC – 2.33 N – 0.26 Av.p – 5.97 Mg – 2.96 K – 0.21
Author's field survey (2011) ****	Effects of deforestation on soil fertility of Delta State, Nigeria.	pH – 4.8 OC – 3.3 N – 0.34 Av.p – 5.01 Mg – 2.4 K - 0.17	pH – 5.29 OC – 4.42 N – 0.43 Av.p – 8.63 Mg – 2.21 K – 0.42

Source: * Oya, et al (1995)

** Chidumayo and Kwibisa (2002)

*** Ezeaku (2002)

**** Author's field work (2011).

As indicated in Table 4.12, Oya et al (1995) in their study on changes in physical and chemical properties of soil in Japan, noted a variation in soil properties of pH, OC, N, Av.p, Mg and K in cultivated and uncultivated plots, Chidumayo and Kwibisa (2002) on effects of deforestation on grass biomass and soil nutrient status in Zambia, noted a variation in similar soil properties of pH, OC, N, Av.p, Mg and K and Ezeaku (2002) in his study on soils of sub-saharan Africa and Management need for sustainable farming, noted a variation in soil properties of pH, OC,N, Av.p, Mg and K in cultivated and uncultivated plots (see table 4.12)

As indicated in Table 4.12, author's field survey (2011), revealed a similar variation in soil properties of pH, OC, N, Av.p, Mg and K in deforested and forested plots. Thus, the author's result is in line or agree with the findings of Oya et al (1995), Chidumayo and Kwibisa (2002) and Ezeaku (2002) on deforestation and soils.

The presence of sufficient soil nutrients in the soil, determines its fertility status. Soil nutrients of pH, OC, Mg, Na, K, Ca, P, N and CEC were considered in determining crop yield and soil fertility. Table 4.11 revealed that Delta North region has the highest soil fertility depletion, followed by Delta Central and Delta South respectively. This is as a result of human activities in the form of continuous and permanent system of cultivation, annual burning of the thick litter of soils, sand escarvation, lumbering and fuelwood exploitation in the area. This has resulted in fertility depletion, and most of the soil synthesis of the crops grown in the area is usually very high when compared with soils of forested area.

4.4.9 Test of Hypothesis Two.

Hypothesis II states that: soil fertility status is not significantly dependent on deforestation in the area.

Table 4.13 Zero Order Correlation Analysis of Effects of Deforestation on Soil Fertility Status.

FORESTED		DEFORESTED											
	Y	A	B	C	D	E	F	G	H	1	J	K	L
Y	1.00												
A	0	1.00											
B	.999	0	1.00										
C	.999	.999	0	1.00									
D	.998	.997	.998	0	1.00								
E	.999	1.00	1.00	.997	0	1.00							
F	.999	0	0	.999	.999	0	1.00						
G	.999	.998	.999	1.00	.998	1.00	0	1.00					
H	.998	.998	.999	0	.998	0	.998	0	1.00				
I	.995	.998	.999	.998	.996	.998	.996	.998	0	1.00			
J	.999	.997	.997	.997	.998	.995	.998	.998	.998	0	1.00		
K	.998	.998	.998	.998	.998	.998	.998	.998	.998	.998	0	1.00	
L	.997	.998	.998	.998	.996	.996	.997	.996	.996	.997	.996	0	

	.777	.997 .777	.997 .771	.996 .787	.769	.997 .775	.787	.775	.794	.787	.775	.794	1.00 0

The zero order correlation analysis showed that deforestation has a significant effect on soil fertility status of Delta State (as shown in Table 4.13.

Table 4.14 Summary of Regression Analysis of Effects of Deforestation on Soil Fertility.

Model	R	R square	Adjusted R square	Std. Error of the Estimate	F	Sig.
1	.940 (a)	.883	.766	1.47274	7.538	.013[a]

a. Predictors: (constant) x11, x9, x4, x8, x3, x7, x6

b. Dependant variable: Soil under forested plot

Table 4.14 reveals that there is a strong correlation with R = 0.940 between deforestation and soil fertility status. However, the r^2 value indicates 0.883 which implies that 88% depletion of soil fertility status is attributed to deforestation, leaving 12% to other factors. At $P< 0.05$, the calculated F value is 7.538 while the critical table value is 3.46. Since calculated value is greater than the critical value, the null hypothesis is rejected and the alternative hypothesis is accepted which states that soil fertility status is significantly dependent on deforestation in the area.

Table 4.15 Standardized Beta Coefficient.

Model	Unstardardized Coefficient		Standardized Coefficient		
	B	Std. Error	Beta	t	Sig.
X3	1.088	1.007	8.462	1.080	0.322

X4	0.978	0.539	7.895	1.816	0.119
X6	-1.179	1.061	-9.120	-1.111	0.309
X7	-.208	0.603	-1.638	-.346	0.741
X8	-.814	0.371	-6.084	-2.194	0.071
X9	1.620	0.358	1.393	4.527	0.004

a. Dependent Variable: Soil under forested plot.

Furthermore, from the standardized beta coefficient values in Table 4.15, the beta values are positive. Thus, deforestation has a significant effect on soil fertility.

4.5 Implication of Observed Soil Properties on the Yield of Yam andCassava.

In terms of physical and chemical properties of soils in Delta State, the total mean values of particle size composition of sand, silt and clay in Table 4.11 for both deforested and forested plots reveal that the soils of the study area are predominantly sandy, and texturally homogeneous (Asadu, C.L.A and Nweke, F.I. 2001). The total mean values obtained from the bulk density and total porosity in Table 4.11 for deforested and forested plots, shows that a variation does not exist between the two sets of soils in terms of bulk density. But a variation exist between the two sets of soils in terms of total porosity. This result implies that soils

under forested plots have a better physical status than deforested plots; because they are less dense and more porous. This is presumably true because forested plots have greater cover (Maclean; Litsinger.; Moody; Watso and Libetario 2003). The low soil pH observed in deforested plots suggest that the crops grown makes a great demand on soil nutrients such as calcium and magnesium, than the grass and tree species of the forested plots (Fasina, 2005). While the higher value of pH in forested plots can be attributed to the release of bases during burning, raises the pH of acid soils (Vine, 2003).

The total mean values of organic matter for both deforested and forested plots, shows that a variation does not exist between the two sets of soils. The greater cover of the forested plots could not have made much impact with regards to addition of more organic matter to the soil because of occasional burning of the forested plots during the dry season, while leaves and stems of cultivated crops are left to decay into the soil in deforested plots at each cultivation, and organic matter accumulates more in the first 20cm of the surface soil (Aduayi, 1985).

The higher value of total nitrogen in deforested plots have been attributed to the decay of leaves and stems of cultivated crops into the soil in each cultivation. The total mean values obtained from available phosphorus for both deforested and forested plots, shows that a variation exist between the two sets of soil. And this may be attributed to the fact that the cultivated crops in the deforested plots absorbs more of this nutrient from the soil (Nnaji; Asadu and Mbagwu 2002). The total mean values obtained from cation exchange capacity in both deforested and forested plots are low. This low value can be attributed to the process of washing away of some dissolved elements such as potassium, calcium and magnesium through the process of leaching to depths lower than those in which plant roots thrives (Aduayi, 1985).

The total mean value of magnesium in deforested plots are higher than the forested plots. This is so because the area is continuously and permanently used for plant growth, most of the soils synthesis in the plant grown is usually very high when compared with the forested plots where cultivation do not take place. The total mean value of potassium in deforested plots are lower, when compared with the forested plots. This is due to the fact that the cultivated crops in the deforested plots absorbs the available potassium that would have helped in improving the soil. The cultivated crops in the area make use of potassium for their maturation and uptake of other elements.

Sodium content is lower in forested plots when compared to the deforested plots. This may be due to leaching and the high rate of sodium absorption by plots that have low sodium content.

The calcium content in the deforested plots is lower, when compared with the forested plots. This may be due to the previously available calcium absorbed by plants each year. Calcium support the activities of soil organization, but since the soil organizations content is not much, due to the effect of continuous and permanent cultivation in the area, the calcium content tend to decline while that of the forested plots is higher. From the above analysis, it is obvious that variation

exist between the two sets of soils in their physical and chemical properties. The variations in the soil physical and chemical properties as a result of deforestation, has the following effects on the yield of yam and cassava in the area.

i. A reduction in the value of organic carbon, total nitrogen and available phosphorus in deforested plots, implies a deteriorating state of the soil in holding water, moderating soil pH and soil temperature (Gilman, 2006).

ii. A reduction in soil pH value in deforested plots, affects nutrients availability for plant growth and leads to disintegration of clay from the soil and accumulation of aluminum and manganese in the soil (Asadu and Enete, 1997).

iii. The low value of cation exchange capacity in deforested plots, implies that the soils are acidic in nature because they are sandy soils that consist mainly of quartz. This has the effect of washing away of some dissolved elements such as potassium (K), Calcium (Ca^{2+}) and Magnesium (Mg^{2+}) through the process of leaching to depths lower than those in which plant roots thrive (Aduayi, 1985). Soil organic matter is rapidly decomposed and oxidized, more nutrients are lost through increased rates of leaching whilst fine humus and mineral particles are either removed by run-off water or translocated lower down the soil (Chidi, 2005).

iv. The low values of potassium and calcium in deforested plots implies a reduction in the activities of soil organization, due to the effect of continuous and permanent cultivation in the area.

v.

Table 4.16 Mean Yield of Yam and Cassava (in Tons/He)

	Locations	Yam (tons)	Cassava (tons)
A	Akwukwu-Igbo	16.36	14.26
B	Ubulu-Ukwu	14.02	18.03
C	Emu-Uno	12.28	9.81
D	Okpai	22.06	12.23
E	Aradhe	10.14	10.20
F	Oleh	17.14	14.04
G	Otor-Owhe	9.52	24.02
H	Ubeji	12.19	20.04
I	Agbarho	18.20	9.12
J	Oghara	14.23	12.16
K	Otor-Udu	8.61	16.14
L	Evwreni	10.42	11.08
	Total	165.2	177.1

Source: Field Survey, 2011

As indicated in Table 4.16, yam has a total yield of 165.2 unit, with Okpai having the highest yield of 22.06 unit and Otor-Udu with the lowest yield of 8.61 unit, while the total yield of cassava is 177.1 unit, with Otor-Owhe having the highest yield of 24.02 unit and Agbarho with the lowest yield of 9.12 unit .

Crop yield depend mainly on nutrient elements of the soil. This means that when the nutrient elements of the soil are taken up by crops grown on it to build their tissues by the way of immobilization, there is bound to be a change in the nutrient status of the soil of the same unit (Gilman, 2006). The cultivation of yam and cassava in the area over the years without recourse to proper soil management method to replenish the soils, has depleted its fertility status, this is evidence from the variation that exists in physico-chemical properties of soils of deforested and forested area (see Table 4.10). And this, has affected the yield of the crop (yam and cassava) in the area. Since the area falls within the ecological zone were root crops like yam and cassava can thrive, with proper soil management to enhance the fertility status of the soils, the yield of yam and cassava in the area will increase.

The presence of sufficient soil nutrients in the soil, determines its fertility (Aduayi, 1985). Soil nutrients of pH, OC, Mg, Na, K, Ca, P, N and CEC are very important in crop cultivation (Erebor, 2009). The role and significance of these soil nutrients in assessing the potential productivity of soils can not be over emphasized. The insufficiency in quantities of these nutrients in the soil constitutes one of the most serious limiting factors on agricultural productivity (Erebor, 2009).

Table 4.17 Mean Soil Properties under Yam Cultivated Plots.

	Locations	pH	OC	Mg	Na	K	Ca	P	N	CEC
A	Akwukwu-Igbo	5.30	4.17	3.41	0.24	0.11	0.15	7.12	0.42	3.6
B	Ubulu-Ukwu	4.92	4.07	3.42	0.03	0.31	0.20	5.9	0.38	3.4
C	Emu-Uno	4.73	1.09	2.75	0.23	0.08	0.48	6.1	0.16	3.2
D	Okpai	4.46	3.88	3.71	0.26	0.09	0.27	6.2	0.24	2.8
E	Aradhe	5.0	4.38	2.02	0.30	0.12	0.13	7.4	0.46	3.1
F	Oleh	4.68	1.14	3.40	0.36	0.08	0.14	7.6	0.6	2.2
G	Otor-Owhe	3.35	4.95	1.07	0.47	0.42	0.08	3.6	0.12	2.6
H	Ubeji	5.26	3.80	0.92	0.03	0.23	0.05	2.1	0.8	2.8
I	Agbarho	4.7	0.22	2.91	0.31	0.30	0.07	3.6	0.2	2.7
J	Otor-Udu	4.8	1.8	2.2	0.2	0.2	0.2	4.3	0.30	2.7
K	Oghara	4.8	2.6	2.6	0.2	0.1	0.2	4.8	0.2	2.7
L	Ewvreni	4.8	2.8	2.8	0.2	0.5	0.2	4.9	0.2	2.8
	Mean	56.8	34.9	30.8	24.2	2.54	2.17	63.6	4.08	34.6

Source: Field Survey, 2011.

As indicated in table 4.17, pH, OC, Mg, and Na has a total mean values of 56.8%, 34.9%, 30.8 and 24.2 respectively. While K and Ca has a total mean of 2.54 and 2.17. And P, N and CEC has a total mean of 63.6, 4.06% and 34.6 respectively.

A variation exists between the observed soil elements of pH, OC, Mg, Na, K, Ca, P, N and CEC in deforested plots when compared with those of forested plots. And the implication of these is that a reduction in the values of organic carbon, total nitrogen and available phosphorus, affects the state of the soil in holding water, moderating soil pH and soil temperature Ogideme (2000) and Gilman, (2006). A reduction in pH value affects nutrients availability for yam growth and leads to disintegration of aluminum and magnesium in the soil (Asadu and Enete, 1997). The low value of cation exchange implies that the soils are acidic in nature and this has the effect of washing away of some dissolved elements such as K, Ca, Mg through the process of leaching. And reduction in the value of potassium and calcium implies a reduction in the activities of soil organization due to the effects of continuous and permanent cultivation in the area.

The implication of these is a reduction in the yield of yam, if the soils of the area is not properly managed.

Table 4.18 Mean Soil Properties under Cassava Cultivated Plots.

	Locations	pH	OC	Mg	Na	K	Ca	P	N	CEC
A	Akwukwu-Igbo	5.0	4.3	3.2	0.16	0.25	0.19	6.93	0.49	3.1
B	Ubulu-Ukwu	4.6	4.2	2.9	0.14	0.15	0.14	5.4	0.48	3.7
C	Emu-Uno	4.0	1.5	2.3	0.10	0.12	0.19	5.6	0.15	2.8
D	Okpai	4.9	4.0	3.1	0.24	0.16	0.36	6.8	0.33	3.3
E	Aradhe	5.2	1.9	3.3	0.28	0.12	0.56	7.1	0.36	2.9
F	Oleh	4.9	1.1	3.1	0.2	0.2	0.2	7.1	0.2	2.2
G	Otor-Owhe	5.2	4.2	1.4	0.2	0.3	0.1	3.4	0.6	2.3
H	Ubeji	4.9	3.6	1.6	0.11	0.2	0.2	2.9	0.4	2.4
I	Agbarho	4.9	1.0	1.5	0.3	0.3	0.2	3.4	0.1	2.5
J	Otor-Udu	4.13	0.39	2.69	0.6	0.22	0.14	5.81	0.36	3.10
K	Oghara	4.07	1.15	3.19	0.9	0.08	0.25	6.32	0.21	2.12
L	Ewvreni	4.06	2.82	3.40	0.12	0.16	0.18	6.18	0.28	2.46
	Mean	55.8	30.2	31.7	3.35	2.26	2.71	66.9	3.96	32.9

Source: Field Survey, 2011.

As indicated in Table 4.18, pH, OC, Mg and Na has a total mean values of 55.8%, 30.2%, 31.7 and 33.5 respectively. While K and Ca has a total mean values of 2.26 and 2.17. And P, N and CEC has a total mean values of 66.9, 3.96% and 32.9 respectively.

A variation exists between the observed soil elements of pH, OC, Mg, Na, K, Ca, P, N and CEC in deforested plots when compared with those of forested plots. And the implication of these is that a reduction in the values of organic carbon, total nitrogen and available phosphorus, affects the state of the soil in holding water, moderating soil pH and soil temperature (Gilman, 2006). A reduction in pH value affects nutrients availability for cassava growth and leads to disintegration of aluminum and magnesium in the soil (Asadu and Enete, 1997). The low value of cation exchange implies that the soils are acidic in nature and this has the effect of washing away of some dissolved elements such as K, Ca, Mg through the process of leaching. And reduction in the value of potassium and calcium implies a reduction in the activities of soil organization due to the effects of continuous and permanent cultivation in the

area. The implication of these is a reduction in the yield of cassava, if the soils of the area is not properly managed.

Crop suitability

Within the broad ecological zones, the distribution of major soil types is largely related to parent materials lithology depth, texture and stoniness, moisture conditions, nutrient status and the proportion of weatherable minerals (Okpor, 2008)

The soils of the study area are deeply weathered, severely leached, friable and they lack distinct and well defined horizons. The soils have a very high content of iron, aluminum, manganese and other oxides diffused throughout the profile (Erebor, 2009). Because of the intensity of weathering and leaching in the area, the soils are highly deficient in weatherable mineral reserves and the clay content is of the kaolin type with low water and nutrient holding capacities. The cations exchange capacity is less than 20me/g per 100g, clay and base saturation is less than 40 percent (Erebor, 2009). The clay ferralsols have a higher fertility than the sandy ones which also suffer from rapid internal drainage and susceptibility to erosion (Okpor, 2008). The combined influence of climate, vegetation and soils determines the pattern of agricultural practice. In Nigeria, it is possible to recognize distinct crop-ecological zones from the humid south to the sub-humid north. In the southern forest zone, where the study area is situated, tree crops cultivated includes cocoa, kolanut, oil palm, rubber, coconut, plantain and banana. Of the food plants grown mainly for home consumptions and internal trade, the root crops that particularly fit into this ecological zone include yam, cassava, cocoyam, and sweet potato. In addition to these major tree and root crops, numerous fruits are grown including pineapple, pawpaw, guava, mango and cashew. Maize, rice and cowpeas are the principal grain crops of the zone, and melon, okro, groundnuts and vegetables are also widely cultivated (Omoruyi; Orhue.; Akerobo and Aghimien 2003).

Since the soil of the study area falls within the ecological zone that tree and root crops can thrive apart from yam and cassava that is majorly cultivated in the area, other crops like plantain, sweet potato, melon, groundnut etc can still be produced as major crops in the area. Thus, with proper soil management these other mentioned crops can compete favourably with yam and cassava being produced as major crops in the area.

4.5.1 Test of Hypothesis Three

The hypothesis states that yield of yam and cassava in the area is not significantly dependent on soil fertility.

$$r = \frac{\sum (x-\bar{x})\ (y-\bar{y})}{\sqrt{\sum (x-x)^2\ (y-y)^2}}$$

Where ∑ = Summation

X = Independent variable

Y = Dependent variable

where y1 = dependent variable (cassava)

y2 = dependent variable (yam) and

x = independent variables Soil pH, Organic Carbon (OC), Magnesium (Mg), Potassium (K), Sodium (Na), Calcium (Ca), Phosphorus (P), Nitrogen (N) and Cation Exchange Capacity (CEC)

Table 4.19 Correlation coefficient explaining the relationship between cassava yield and soil nutrients.

					Change statistics				
Model	R	R sqr.	Adjusted R sqr.	Std. Error of the Estimate	R sqr. Change	F change	df1	df2	Sig. F change
1	0.997	0.993	0.974	0.21167	0.993	49.993	6	2	0.020

a predictors (constant), Ca, pH, OC, Mg, K, Na, P, N, CEC

Table 4.19 reveals that there is a strong correlation with R = 0.997 between cassava yield and soil nutrient characteristics, leaving just 1% to other factors. However, the r^2 value indicates 0.993 which implies that 99% of the cassava yield is attributed to soil nutrient characteristic. At P = <0.05, the calculated F value is 49.993 while the critical table value is 19.33. Since, calculated value is grater than critical value, the null hypothesis is rejected and the alternative hypothesis is accepted which states that yield of yam and cassava in the area is significantly dependent on soil fertility. This result signifies that the yield of crops (yam and cassava) depends on soil neutrients for its productivity.

Table 4.20 Correlation coefficient explaining the relationship between yam yield and soil nutrient characteristics.

					Change statistics				
Model	R	R sqr.	Adjusted R sqr.	Std. Error of the Estimate	R sqr. Change	F change	df1	df2	Sig. F change
1	0.993a	0.986	0.994	0.47446	0.986	23.372	6	2	0.042

a predictors (constant), Ca, pH, OC, Mg, K, Na, P, N, CEC

Table 4.20 reveals that there is a correlation with R = 0.993 between yam yield and soil nutrient characteristics. However, the r^2 value indicates 0.986 which implies that 98% of the yam yield is attributed to soil nutrient characteristics. At $P < 0.05$, the calculated F value is 23.373 while the critical value is 19.33. Since calculated value is grater than the critical value, the null hypothesis is rejected and the alternative hypothesis is accepted which states that there is a positive relationship between soil nutrient characteristics and crop yield (yam). This result signifies that the yield of crop has a strong relationship with soil fertility in respect of yield of crops studied under the three ecological zones in Delta State.

It is observed that there is a positive relationship between soil nutrient characteristics and crop yield (cassava and yam) (see Tables 4.19 and 4.20).

Table 4.21 Standardized beta coefficient.

Model	Un-standardized Coefficient		Standardized coefficient	t	Sig.
	B	Std. error	Beta		
t-(constant)	-5.095	1.776		-2.868	0.103
pH	3.111	0.390	0.585	7.974	0.015
OC	-2.41	0.054	0.438	-4.446	0.047
Mg	-.898	0.156	0.541	-5.746	0.029
K	-1.406	1.125	0.100	-1.250	0.338
Na	-6.608	1.618	0.459	-4.083	0.055
Ca	-5.221	1.557	0.508	-3.354	0.079

P	-3.122	0.066	0.421	-5.421	0.57
N	-2.68	0.107	0.532	-1.233	0.81
CEC	-4.336	1.534	0.502	-3.236	0.98

a. dependent variable: cassava

Furthermore, from the standardized beta coefficient values in table 4.21, the beta values are positive for pH. This implies that as the soil pH increases so also the cassava yield increases.

Table 4.22: Standardized Beta Coefficient

Model	Un-standardized Coefficient		Standardized coefficient	t	Sig.
	B	Std. error	Beta		
1.(constant)	31.241	3.981		7.847	0.016
pH	-5.731	0.874	0.701	-6.554	0.022
OC	-.652	0.121	0.772	-5.373	0.033
Mg	-.339	0.350	0.133	0.969	0.435
K	-12.968	2.523	0.598	-5.141	0.36
Na	9.982	3.627	0.450	2.752	0.111
Ca	-.040	3.489	0.003	-.011	0.992
P	-.348	2.431	0.664	-2.654	0.49
N	-.561	2.685	0.536	-3.851	0.126
CEC	-.8932	3.364	0.468	-4.632	0.891

a. Dependent variable: yam

From the standardized beta coefficient values in Table 4.22, the beta values are positive for Na. This implies that as Na increases so also the yam yield increases. Thus, from Tables 4.21 and 4.22, it is revealed that increasing soil nutrients leads to corresponding growth in the yield of cassava and yam.

4.6 Soil Management Methods.

The soil management method practiced by the farmers in the twelve locations of the study area include fallow system, slash and burn, tillage and soil amendments methods.

The study by Asadu and Nweke (2001) showed that an ecological balance of nutrients and soil organic matter (SOM) can be achieved with the fallow system. The fallow system of soil management is beneficial and efficient, but considering the fact that a very small proportion of the forest land are being cultivated, thus the achievement of sustainability by this system can not support the increasing population of the area.

Farmers in the area use the slash and burn method to incorporate into the soil some of the materials accumulated in the vegetative cover during fallow. The burnt ash contains elements such as calcium (Ca) Magnesium (Mg) Potassium (K) and Sodium (Na), which are added to the soil such that the soil pH is remarkably improved. Though the plant ash resulting from the slash and burn method, improves the soil pH remarkably, it conserves moisture and restores organic matter and nutrients to the soil and also controls weed, insects and various pathogens population (Asadu and Nweke, 2001), burning results in most of nitrogen, sulphur and carbon being lost as gases. Areola (1990) reported that annual bush burning is likely to compound the problem of soil deterioration.

The tillage system of soil management adopted by the farmers, creates a soil environment favourable to plant growth. Since tillage operations may loosen, granulate, crush or even compact the soil, certain soil factors which influence plant growth such as bulk density, pore size distribution and thus the composition of soil air are generally influenced (Lal, 2000). Intensive tillage has been reported to lead to rapid oxidation of soil organic matter (SOM), while minimum and zero tillage system do not endanger the content of soil organic matter (SOM) when used for seedbed (Kunde, 1995).

While the soil amendments used by the farmers are mineral and organic ferterlizers. The purpose of its application is to replace the major nutrients like NPK lost through runoff, leaching and crop removal. The work by Asadu and Nweke (2001), has shown that a combination of NPK fertilizer mixture and 250 t/ha of organic manure was superior to the use of inorganic ferterlizer alone in improving soil productivity. The application of soil amendments into farm plots, improves the soil organic matter status (Areola, 1990).

As indicated in Table 4.23, the mean values for sand, silt and clay are 89.5%, 4.7% and 4.8% for fallow plots, 87.1%, 5.5% and 6.7% for tillage plots, 88.4%, 5.9% and 5.9% for soil amendment plots, and 84.1%, 10.2% and 5.4% for slash and burn plots. The mean values for Bulk Density, Total Porosity and Soil pH are 1.5, 62.5% and 4.6 for fallow plots, 1.2, 60.9% and 4.9 for tillage plots, 1.2, 68.7% and 5.2 for soil amendment plots and 1.3, 59.2% and 4.9 for slash and burn plots. The mean values for Organic Carbon, Total Nitrogen, Available Phosphorous and CEC are 4.2%, 0.48%, 5.3 and 3.7 for fallow plots, 1.1%, 0.2%, 7.1 and 2.2 for tillage plots, 4.2%, 0.6%,3.4 and 2.3 for soil amendment plots and 3.6%, 0.4%, 2.9 and 2.4 for slash and burn plots. And the mean values for magnesium, potassium, sodium and calcium are 2.9, 0.15, 0.14 and 0.14 for fallow plots, 3.1, 0.2, 0.2 and 0.2 for tillage plots, 1.4, 0.3, 0.2 and 0.1 for soil amendment plots and 2.5, 0.18, 0.15 and 0.15 for slash and burn plots.

Table 4.23

Table 4.24 Mean Yield of Yam (in Tons/He) under Different Soil Management Methods in Delta State.

Locations	Fallow plot	Slash and burn plot	Tillage plot	Soil amendments	Total yield kg/ha.
A- Akwukwu-Igbo	5.22	4.04	3.04	4.06	16.36
B- Ubulu-Ukwu	4.10	3.26	3.18	3.48	14.02
C- Emu-Uno	4.81	2.14	2.23	3.10	12.28
D- Okpai	5.62	3.46	3.20	4.86	17.14
E- Aradhe	3.14	2.04	2.10	2.86	10.14
F- Oleh	6.92	4.52	4.66	5.96	22.06
G- Otor-Owhe	3.10	2.02	2.06	2.34	9.52
H- Ubeji	4.78	2.11	2.20	3.10	12.19
I- Agbarho	6.02	3.58	3.48	5.12	18.20
J- Oghara	4.16	3.31	3.23	3.53	14.23
K- Otor-Udu	2.41	2.02	2.06	2.12	8.61
L-Evwreni	3.24	2.04	2.06	3.08	10.42
Total	53.52	33.52	33.5	44.61	165.2

Field Survey, 2011

Table 4.25 Mean Yield of Cassava (in Tons/He) under Different Soil Management Methods in Delta State.

Locations	Fallow plot	Slash and burn plot	Tillage plot	Soil amendments	Total yield kg/ha.
A- Akwukwu-Igbo	4.17	3.32	3.23	3.54	14.26
B- Ubulu-Ukwu	6.02	3.52	3.41	5.08	18.03
C- Emu-Uno	3.18	2.09	2.13	2.41	9.81
D- Okpai	4.76	2.14	2.26	3.07	12.23
E- Aradhe	3.14	2.08	2.12	2.86	10.20
F- Oleh	4.10	3.26	3.20	3.48	14.04
G- Otor-Owhe	7.96	4.52	4.46	6.88	24.02
H- Ubeji	6.14	4.47	4.31	5.12	20.04
I- Agbarho	2.80	2.03	2.05	2.24	9.12
J- Oghara	4.75	2.10	2.18	3.13	12.16
K- Otor-Udu	5.62	3.46	3.20	3.86	16.14
L-Evwreni	3.65	2.37	2.35	3.43	11.08
Total	56.29	35.36	35.11	45.1	177.1

Field Survey, 2011

Tables 4.24 and 4.25 shows the mean yield of yam and cassava under different soil management methods practiced by the farmers in the twelve locations of the study area. It revealed a total of 53.52 tons/he and 56.29 tons/he of yam and cassava in fallow plots. The slash and burn plots recorded 33.52 tons/he and 35.36 tons/he respectively, tillage plots recorded 33.5 tons/he and 35.11 tons/he respectively for yam and cassava, while the soil amendment plots recorded 44.61 tons/he and 45.1 tons/he respectively for yam and cassava.

From this analysis, its obvious that the fallow method proved otherwise by recording the highest yield of 53.52 tons/he and 56.29 tons/he. This is followed by soil amendments which recorded 44.61 tons/he and 45.1 tons/he, the slash and burn method which recorded a total yield of 33.52 tons/he and 35.36 tons/he, while the tillage method recorded the least yield of 33.5 tons/he and 35.11 tons/he for yam and cassava respectively.

4.6.1 Testing of Hypothesis Four.

The hypothesis states that the different soil management methods adopted has no significant improvement on the nutrient status of the soil.

Where,

Y1 = dependent variable (soil nutrient) and

X = independent variable (tillage, fallowing, slash and burn, soil amendments).

Table 4.26 Correlation coefficient explaining soil management and soil nutrient.

					Change statistics				
Model	R	R sqr.	Adjusted R sqr.	Std. Error of the Estimate	R sqr. Change	F change	df1	df2	Sig. F change
1	0.999a	0.999	0.999	1.06184	0.999	2890.463	3	10	0.000

a . Predictors (constant) Tillage, Fallowing, Slash and Burn, Soil Amendments.

Table 4.26 reveals that there is a correlation with R = 0.999 between soil management technique and soil nutrient. However, the r^2 value indicates 0.999, which implies that 99% of the soil nutrient is attributed to soil management technique. At $P <0.05$, the calculated F value is 2890.464 while the critical table value is 3.71. Since calculated value is greater than critical value, the null hypothesis is rejected and the alternative hypothesis is accepted which states that the different soil management methods adopted has significant improvement on the nutrient status of the soil. This result signifies that the soil management methods of fallow, soil amendments, tillage and slash and burn techniques has a significant improvement on the yield of crops (yam and cassava) in Delta State.

Table 4.27 Standardized Beta Coefficient.

Model	Un-standardized coefficient		Standardized coefficient	t	Sig.
	B	Std. error	Beta		
1. (constant)	0.640	0.347		1.847	0.094
Fallowing	0.732	0.261	0.714	2.801	0.019
Slash & burn	0.247	0.547	0.231	0.451	0.661
Tillage	0.057	0.626	0.054	0.090	0.930
Soil amendments	0.346	0.482	0.321	0.568	0.247

a. Dependent variable: soil properties.

Furthermore, from the standardized beta coefficient values in Table 4.27, the beta values are positive. Thus, as the soil management method improves, so also the soil nutrients improves. However, the most significant management method is the fallowing, followed by soil amendments, slash and burn and tillage methods respectively.

4.7 Comparative Study of the Yield of Yam and Cassava among the Three Regions in Delta State

Table 4.28 Mean Yield of Yam and Cassava (in tons/he) among the Three Regions in Delta State

Regions/locations	Yam	Cassava
Delta North		
Akwukwu-Igbo	16.36	14.26
Ubulu-Ukwu	14.02	18.03
Emu-Uno	12.28	9.81
Okpai	17.14	12.23
Total	**59.80**	**54.33**
Delta Central		
Agbarho	10.14	10.20
Oghara	22.06	14.04
Otor-Udu	9.52	24.02
Evwreni	12.19	20.04
Total	**53.91**	**68.3**
Delta South		
Aradhe	18.20	9.12
Oleh	14.23	12.16
Otor-Owhe	8.61	16.14
Ubeji	10.42	11.08
Total	**51.46**	**48.5**
Grand total	**165.2**	**177.1**

Source: Field Survey, 2011

Table 4.28 shows the mean and total yield of yam and cassava among the three regions of Delta State. It revealed that Delta North region has the highest total yield of yam, followed by Delta Central and Delta South with corresponding values of 59.80 (tons/he), 53.91 (tons/he) and 51.46 (tons/he) respectively. While Delta Central has the highest total yield of cassava, followed by Delta North and Delta South with corresponding values of 68.3 (tons/he), 54.33 (tons/he) and 48.5 (tons/he) respectively. The highest yield of yam and cassava observed in both Delta North and Delta Central respectively, signifies better soil fertility status. This could also be attributed to improved soil management method adopted by the farmers in the regions. While the lowest yield of yam and cassava observed in Delta South, signifies depletion in soil fertility status. This could also be attributed to poor soil management method adopted by the farmers in the region.

4.7.1 Testing Hypothesis Five

The hypothesis states that there is no significant difference in the yield of yam and cassava among the three regions of Delta State

Table 4.29 Summary of Analysis of Variance (ANOVA) showing variation in crop yield among the three regions of Delta State.

Sources of variation	DF	Sum of squares	Variance	F Ratio calculated	F Ratio critical	Remark
Within sample	7	27599.04	2.759.81	7.526	4.72	Significant
Between sample	2	64599.2	2.6280.7			
Total	9					

Table 4.29 revealed that there is a moderate variation in the yield of yam and cassava among the three regions of Delta State. At $P < 0.05$, the calculated F value is 7.526 while the critical value is 4.72. Since calculated value is greater than the critical value, the null hypothesis is rejected and the alternative hypothesis is accepted.

Table 4.30 Tukey Test Analysis

Regions	Calculated Value	Table Value
Delta North	0.05 *	3.76
Delta Central	0.03 *	3.76
Delta South	0.01 *	3.76

Note: * Significant at 0.05 level

Table 4.30 revealed that there is no significant variation among the three regions of Delta State in the yield of yam and cassava cultivation. Thus, the three regions compared shows a significant difference. This result signifies that the significant difference exist in the yield of crops (yam and cassava) in Delta State, with Delta North having the highest yield followed by Delta Central and Delta South respectively.

CHAPTER FIVE.

SUMMARY OF FINDINGS, CONCLUSION AND RECOMMENDATIONS.

5.1 SUMMARY OF FINDINGS.

This study assessed the effect of deforestation on soil fertility in Delta State, Nigeria. In achieving this aim, the study focused on the measurement of vegetation physiognomy and analysis of soil samples sourced through direct field work on deforested and forested areas in Delta State. The data upon which this work premised were analysed in order to compare vegetation physiognomy of deforested and forested areas examine the effects of deforestation on soil nutrients, assess the implication of observed soil properties on the yield of yam and cassava in the area, determine the most effective soil management method adopted over the years, compare the yeild of crops (yam and cassava) among the three regions of Delta State and suggest possible ways of soil improvement under deforested plots.

The study also tested the five posited hypotheses using the t-test as appropriate statistical technique to test hypothesis 1. While the analysis of variance (Anova) was used to test hypothesis five. The study also provided answers to research questions posited in the course of the study. Also, graphs, tables, maps and percentages were used to present and analyse the data collected for the study.

Subsequently, the following findings have been made as follows:-

It was revealed from the analyzed data of vegetation physiognomy that a variation exist in tree species in forested and deforested areas. 48.1% of *milicia excelsa* been lost to deforestation. Others showed 25.5%, 7.3%, 12.7% and 12.7% degradation for *khaya spp*., *pentacethra macophylla, antiaris africana* and *irvingia gabonensis* respectively. Moreso, the study revealed that a variation exist in species distribution in the area. The dominant tree species available in both forested and deforested areas is the *milicia excelsa* (iroko tree) and the least tree specie available is the *pentaclethre macrophylla* (oil bean tree). It also revealed that more variety of tree species is found in Okpai in both forested and deforested area while very few varieties of species are found in Ewvreni for forested and deforested area.

Findings from the study also revealed that variation exist in the number of available trees in both deforested and forested areas in Delta State. However, the number of trees per quadrant found in the entire deforested area is lesser than those of the forested area and this is evidence from 236 trees and 456 trees observed in both deforested and forested areas. Moreso, the study revealed that the population pressure accounted for 57.6% as the major causes of deforestation in the area. While fuel wood accounted for 30.5% as the least of the cause of deforestation. Other causes of deforestation are farming 48.2%, lumbering 40.7% and infrastructural development 47%. The implication of these is that it reduces the quality and quantity of woody structure of landscape through the process of fragmentation, which is related to deforestation and loss of forest cover (Noss, 1999 and Fitzsimmons, 2003).

The study also revealed from the analyzed data from soil samples that a variation exists in physico-chemical properties of soil of deforested and forested areas. The total mean values for sand, silt and clay for deforested plots are 88.4%, 4.82% and 5.00%, while those of forested plots are 90.3%, 4.59% and 5.53% respectively. The values for bulk density, total porosity, soil pH and organic carbon for deforested plots are 1.34, 60.9%, 4.86 and 4.14%, while that of forested plots are 1.31, 68.2%, 5.29 and 4.42% respectively. The values for total nitrogen, available phosphorus, and CEC are 0.33%, 5.01 and 2.77, while that of forested plots are 0.43%, 8.63 and 3.98 respectively. And the values for Magnesium, Potassium, Sodium and Calcium for deforested plots are 2.53, 0.17, 0.19 and 0.21, while that of forested plots are 2.21, 0.42, 0.16 and 0.56 respectively.

The result of hypothesis one shows that a significant variation exist in the number of tree species present in deforested and forested area. This is evident from the paired t-test analysis, where the calculated t value of 7.642 is grater than the critical table value of 2.843 at $P < 0.05$. Moreso, hypothesis two shows that deforestation has significant effect on soil fertility status. This is evident from the r^2 value of .883, which implies that 88% of soil fertility depletion is attributed to deforestation. Hence the null hypothesis was rejected.
The result of hypothesis three shows that the yield of yam and cassava in the area is significantly dependent on soil fertility. This is evident from the r^2 values of 0.993, which implies that 99% of crop yield (yam and cassava) is attributed to soil nutrient characteristics. Hence the null hypothesis was rejected. The result of hypothesis four shows that the different soil management methods have significant improvement on the nutrient status of the soil. This is evident from the r^2 value of 0.999, which implies that 99% of the soil nutrient is attributed to soil management technique. Hence the null hypothesis was rejected. The result of hypothesis five shows that a significant variation exists among the three regions in Delta State in their yield of crops (yam and cassava). This is evident from the Anova test, where the calculated F value of 7.526 is greater than the critical value of 4.72 at $P < 0.05$.

The results of the analysis showed that the soils under the two landuse types were largely homogeneous in terms of textural composition in their surface layers. They were predominantly sandy with a clay fraction of less than 10% (see Table 4.10).

It was also observed that organic matter content and concentration of total nitrogen varies in both landuse soils. Although the soils of the whole area are acidic in nature, probably due to heavy annual rainfall. Soils of the deforested plots are more acidic than the forested plots. Unlike soil pH, which is higher in forested plots, available phosphorus, CEC, Potassium and Calcium concentration is higher in forested plots. While magnesium and sodium concentration is higher in deforested plots.

The implication of these is that soil physical status deteriorated as a result of deforestation. Soils in the deforested plots are more compact and less porous than the forested plots. Thus deforestation affects the physical and chemical properties of soils in Delta State .

5.2 CONCLUSION

This study has examined the effects of deforestation on soil fertility in Delta State, Nigeria. The study revealed that variation exist in the number of available
tree species present in both deforested and forested area in Delta State. The study also revealed that deforestation has a significant effects on the soil characteristics in Delta State. Similarly, the soil management methods of fallowing, tillage and slash and burn methods adopted by the farmers, has significantly improved the soil nutrient status and the yield of yam and cassava in the state. It therefore recommended that: liming should be introduced as a measure of reducing soil acidity. Mulching should be introduced, to help conserving soil structure, organic matter and nutrient status. Farmers education on soil conservation should be encouraged

It is believed in order to make these suggestions as to what needs to be done to promote the conservational use in Delta State soil resources, two very important requirements for promoting soil productivity and conservation are evident from the various indigenous soil management techniques practiced by the farmers in the area. The first is to protect the soils against desiccation and accelerated erosion especially during the cultivation period. The second is to sustain the buffering capacities and the nutrient status of the soils, through the maintenance of soil humus level. Modern scientific intervention will only be meaningful if it seeks to enhance these two positive aspects.

5.3 RECOMMENDATIONS

Having observed the various reasons for the decline in the soil fertility status of deforested plots in Delta State, there is need for recommendations and suggestions in the area of study so that the soil fertility under deforested plots can be increased. In order to optimally utilize the soils of deforested plots, and bearing in mind the adverse effect of excessive tillage, yam and cassava cultivation in the area should be modernized. In fact, modernized farming would be very much suitable because of the extensive landmass of the area. Modernization involves the use of modern implements like plough, harrow, ridger and also the use of agro-chemicals like insecticides, herbicides, fertilizers and improved seeds in the farm plots. But considering the economic, technical know-how, small farm operation factors, as hindrance to modernization for local farmers in the area, calls for urgent attention from the government, non-governmental organizations and research institutes, whose roles will be beneficial in promoting soil productivity and enhancing crop yields. These bodies should provide easy access to farm credit facilities to the local farmers, to enable then engage in the practice effectively. Moreso, the body should foster crop-change approach by developing and introducing new and several varieties of crops for the farmers in the area. These new varieties will either be the early maturing or more high yielding varieties.

Secondly, the heavy rainfall experienced in the area would obviously cause soil erosion and leaching in deforested plots, therefore the use of zero or minimum tillage should be introduced to curb the problem, as against the intensive tillage practiced by the farmers. Since the soils are acidic in nature, liming should be introduced as a measure for reducing soil acidity.

Thirdly, since the cation exchange capacity of the soils are low, a substantial part of the nutrients in organic fertilizer applied to the soil will be leached away during cropping. It will be necessary for the farmers in the area to adopt measure such as mulching, which will help to conserve soil structure, organic matter and nutrient status (Sanchez, 2008). This has the advantage of reducing the rate of soil water evaporation, the direct impact of solar energy, weed growth and competition with crops (Wakene, 2003).

Fourthly, proper rotational programmes of crops are needed, inorganic manure, farm yard manure and poultry droppings should be incorporated into the soils, to maintain fertility.

Fiftly, the farmers should equally be educated on proper soil management techniques and farming methods that will help in improving soil fertility status, and agricultural productivity and controlled deforestation which its adverse impact on soil leads to removal of soil nutrients.

Lastly, Intensification of silvicultural activities should be encouraged to promote the growth of both exotic and indigenous tree species.

5.4 CONTRIBUTION TO KNOWLEDGE.

The study has contributed in the area of bio-geographical studies especially in the area of tree species loss occasioned by anthropogenic activities of man. The study clearly outlined that the application of fertilizer, bush fallow, slash and burn and tillage systems are the most appropirate soil management techniques adopted to enhance soil fertility and good yield of crops in Delta State. It has also contributed in the area of soil study and pedology by clearly establishing that deforestation is responsible for soil fertility depletion in Delta

State. Moreso, the study clearly demonstrated that in view of the soil status of Delta State, that yam/cassava are the most suitable crops which is of paramount importance in the area of crop science.

5.5 LIMITATION OF THE STUDY

A major constrain of concern arising from this study was the large amount of capital required for the analysis of soil sample collected and analysed.

Also, moving round the plots in collecting data, some farmers were hostile and questions were asked on what we want to use the soil for, the researcher has to look for other farm plots where the owners are friendly before soil samples were collected. Also because of the high cost of some reagents, such parameters as trace element could not be analysed and used for this study such as lead, cadmium, nickel, boron.

5.6 SUGGESTION FOR FURTHER STUDY

For the study to be all encompassing and embracing, studies should be carried out in other areas to determine their level of soil fertility status as regard the effects of deforestation on soil characteristics, so that a comparison can be made and conclusion drawn. It will also enhance a better understanding of soil characteristics
in deforested areas in Nigeria. Such studies should cover all the physical-chemical characteristics of soil.

Researchers are also needed to carry-out detailed study on the effects of yam and cassava cultivation on soil physical-chemical characteristics of soil and the effects of flooding and bush burning on soil physical-chemical properties in Delta State.

Also studies on agricultural landuse and soil management situations should be carried out in order to determine how soil fertility depletion can be minimized either on a continuous cultivated plots or permanent cultivated plots.

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APPENDIX 1: QUESTINNAIR

Dear Respondent,

This questionnaire is designed for the purpose of research on the study of effect of deforestation on soil fertility in Delta State of Nigeria. All cooperation in responding to these questions will be highly appreciated. This research work is purely academics. The information given will be treated with utmost confidence.

Thanks
Ugboma Paul Peters

Section A (BIODATA).

1. Place of residence …………………………………………………
2. Sex of respondents (a) Male [ ] (b) Female [ ]
3. Age (a) 15-25 [ ] (b) 26-35 [ ] (c) 36-45 [ ] (d) 46 and above
4. Marital status (a) single [ ] (b) Married [ ] (c) Divorced [ ]
   (d) Widow [ ]
5. Educational status (a) Primary [ ] (b) Secondary [ ] (c) Tertiary [ ]
6. Occupation (a) Self employed [ ] (b) Civil Servant [ ] (c) Farmer [ ]

SECTION B: CAUSES OF DEFORESTTION

7. Indicate the factor that causes deforestation in the area in order of severity, where 5- very high, 4- high, 3- moderate, 2- low, and 1- extremely low influence

	Severity influence				
Causes of deforestation					
Farming					
Population pressure					
Infrastructural development					
Lumbering					
Fuel wood					

8. What type of fuel do you use for domestic cooking? (a) Firewood [ ],

(b) Charcoal [ ] (c) Gas [ ] (d) Sawdust [ ]

SECTION C: EFFECT OF DEFORESTATION

9. Is there a high rate of deforestation in the area ? (a) Yes [ ] (b) No [ ]
10. Which among these environmental problems is caused by deforestation?
(a) loss of biodiversity [ ] (b) Increased temperature [ ] (c) flooding [ ] (e) loss of nutrient [ ]
11. Have you noticed any changes in the weather of the area? (Yes [ ]
(b) No [ ]
12. Tick the appropriate way of checking deforestation (a) practicing aforestation [ ] (b) avoidance of indiscriminate lumbering [ ] (c) imposition of fines on illegal loggers [ ] (d) Avoidance of shifting cultivation [ ]

APENDIX II

TEST FOR QUESTIONNAIRE RELIABILITY

S/n	Questions	Parameters	X	Y	X^2	Y^2	XY
I	What type of fuel do you use for domestic cooking?	Firewood Charcoal Kerosene Gs Saw dust	10 10 10 10 10	10 10 10 10 10	100 100 100 100 100	100 100 100 100 100	100 100 100 100 100
II	Is there an high rate of deforestation in the area?	Yes No	4 6	3 7	16 36	9 49	12 42
Total			80	80	752	758	754

$$= \frac{9\,(754) - (80)\,(80)}{\sqrt{9\,(758) - (80)^2 \;\; x\;(752) - (80)^2}}$$

$$= \frac{6786 \;-\; 6400}{\sqrt{6822 - \; 6400 \; - 6768 \; - 6400}}$$

$$= \frac{386}{\sqrt{155296}}$$

$$= \frac{386}{394.08}$$

$$= 0.98$$

APPENDIX I11

SPSS OUTPUT FOR MULTIPLE REGRESSION

Descriptive Statistics

	Mean	Std. Deviation	N
Y	9.8085	24.31985	13
X1	9.7015	24.57529	13
X2	9.4008	24.15077	13

X3	9.2123	23.66400	13
X4	9.4838	24.55633	13
X5	9.2708	23.87935	13
X6	9.2077	23.91297	13
X7	9.1231	23.54264	13
X8	9.0238	22.74921	13
X9	9.5923	22.73592	13
X10	9.2156	23.65821	13
X11	9.3861	22.81964	13
X12	2.8942	2.61644	13

Correlations

		Y	X1	X2	X3	X4	X5
Pearson Correlation	Y	1.000	.999	.999	.998	.999	.999
	X1	.999	1.000	.999	.998	.999	.998
	X2	.999	.999	1 .000	.997	1.000	.999
	X3	.998	.999	.999	1.000	.999	.999
	X4	.999	.997	.998	.999	1.000	.998
	X5	.999	1.000	.998	.999	.997	1.000
	X6	.999	.998	1.000	.999	.998	1.000
	X7	.999	.998	.999	1.000	.998	.999
	X8	.999	.998	.998	.998	1.000	.998
	X9	.998	.998	.998	.998	.998	1.000
	X10	.998	.997	.997	.999	.997	.997
	X11	.995	.997	.997	.997	.996	.995
	X12	.777	.777	.771	.787	.769	.775

Correlations

		X6	X7	X8	X9	X10	X11	X12
Pearson Correlation	Y	.999	.999	.999	.998	.998	.995	.777
	X1	.998	.998	.998	.998	.997	.997	.771
	X2	.998	.998	.998	.998	.997	.997	.771
	X3	1.000	.998	.998	.997	.997	.995	.771
	X4	.998	.998	.998	.996	.996	.996	.775
	X5	.998	.998	.998	.996	.996	.996	.769
	X6	.999	.998	.998	.997	.997	.996	.768
	X7	.999	.998	.998	.998	.997	.996	.768

X8	.999	.998	1.000	.998	.997	.996	.775
X9	1.000	.999	.999	1.000	.997	.998	.787
X10	1.000	.999	.999	.998	1.000	.998	.787
X11	.996	.996	.998	.997	.998	1.000	.794
X12	.787	.775	.775	7.87	.776	.776	1.000

Correlations

	Y	X1	X2	X3	X4	X5	X6
Sig. (i-tailed) Y		.000	.000	.000	.000	.000	.000
X1	.000		.000	.000	.000	.000	.000
X2	.000	.000		.000	.000	.000	.000
X3	.000	.000	.000		.000	.000	.000
X4	.000	.000	.000	.000		.000	.000
X5	.000	.000	.000	.000	.000		.000
X6	.000	.000	.000	.000	.000	.000	
X7	.000	.000	.000	.000	.000	.000	.000
X8	.000	.000	.000	.000	.000	.000	.000
X9	.000	.000	.000	.000	.000	.000	.000
X10	.000	.000	.000	.000	.000	.000	.000
X11	.000	.000	.000	.000	.000	.000	.000
X12	.000	.000	.000	.000	.000	.000	.000
Y	13	13	13	13	13	13	13
X1	13	13	13	13	13	13	13
X2	13	13	13	13	13	13	13
X3	13	13	13	13	13	13	13
X4	13	13	13	13	13	13	13
X5	13	13	13	13	13	13	13
X6	13	13	13	13	13	13	13
X7	13	13	13	13	13	13	13
X8	13	13	13	13	13	13	13
X9	13	13	13	13	13	13	13
X10	13	13	13	13	13	13	13
X11	13	13	13	13	13	13	13
X12	13	13	13	13	13	13	13

Correlations

	X7	X8	X9	X10	X11	X12
Sig. (i-tailed) Y	.012	.015	.015	.012	.000	.000
X1	.000	.000	.000	.000	.000	.000
X2	.000	.000	.000	.000	.000	.000
X3	.000	.000	.000	.000	.000	.000
X4	.000	.000	.000	.000	.000	.000
X5	.000	.000	.000	.000	.000	.000
X6	.000	.000	.000	.000	.000	.000
X7		.000	.000	.000	.000	.000
X8	.000		.000	.000	.000	.000
X9	.000	.000		.000	.000	.000
X10	.000	.000	.000		.000	.000
X11	.000	.000	.000	.000		.001

X12	.001	.001	.001	.001	.001	
N Forested	13	13	13	13	13	13
X1	13	13	13	13	13	13
X2	13	13	13	13	13	13
X3	13	13	13	13	13	13
X4	13	13	13	13	13	13
X5	13	13	13	13	13	13
X6	13	13	13	13	13	13
X7	13	13	13	13	13	13
X8	13	13	13	13	13	13
X9	13	13	13	13	13	13
X10	13	13	13	13	13	13
X11	13	13	13	13	13	13
X12	13	13	13	13	13	13

Model Summary

Model	R	R square	Adjusted R square	Std. Error of the Estimate
1	.940a	.883	.766	1.47272

a. Predictors: (constant) X11, X9, X4, X8, X3, X7, X6

Anova

Model	Sum of squares	df	Mean square	F	Sig.
1 Regression Residual Total	98.102 13.014 111.116	6 6 12	16.350 2.169	7.538	.013

a. Predictors: (constant) X11, X9, X4, X8, X3, X7, X6
b. Dependent Variable Forested.

Coefficient

Model	Unstandardized Coefficient			
	B	Std. Error	F	Sig.
1 (constant)	.159	.714	.223	.831

a. Dependent Variable Forested

Coefficients[a]

Model		95.0% Confidence Interval for B	
		Lower Bound	Upper Bound
1	(Constant)	-1.587	1.906

a. Dependent Variable: Foresfed

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	X3	1.088	1.007	8.462	1.080	.322
	X4	.978	.539	7.895	1.816	.119
	X6	-1.179	1.061	-9.120	-1.111	.309
	X7	-.208	.603	-1.638	-.346	.741
	X8	-.814	.371	-6.084	-2.194	.071
	X9	1.620	.358	1.393	4.527	.004

a. Dependent Variable: Foresfed

Coefficients[a]

Model		95.0% Confidence Interval for B	
		Lower Bound	Upper Bound
1	X3	-1.377	3.553
	X4	-.340	2.296
	X6	-3.775	1.417
	X7	-1.684	1.267
	X8	-1.723	.094
	X9	.744	2.495

a. Dependent Variable: Foresfed

Excluded Variables[b]

Model						Collinearity Statistics
		Beta In	t	Sig.	Partial Correlation	Tolerance
1	X1	41.028[a]	3.555	.016	.847	4.986E-5
	X2	-14.844[a]	-.746	.489	-.316	5.323E-5
	X5	-36.355[a]	-3.287	.022	-.827	6.058E-5

a. Predictors in the Model: (Constant), X9, X4, X8, X3, X7, X6

b. Dependent Variable: Foresfed

Residuals Statistics[a]

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	.1559	90.3247	9.8085	24.31558	13
Residual	-1.01991	.78928	.00000	.45547	13
Std. Predicted Value	-.397	3.311	.000	1.000	13
Std. Residual	-1.583	1.225	.000	.707	13

a. Dependent Variable: Y

APPENDIX IV

Data for Hypothesis three

Mean Yield of Yam and Cassava (in Tons/He)

	Locations	Yam (tons)	Cassava (tons)
A	Akwukwu-Igbo	16.36	14.26
B	Ubulu-Ukwu	14.02	18.03
C	Emu-Uno	12.28	9.81
D	Okpai	17.14	12.23
E	Aradhe	10.14	10.20
F	Oleh	22.06	14.04

G	Otor-Owhe	9.52	24.02
H	Ubeji	12.19	20.04
I	Agbarho	18.20	9.12
J	Oghara	14.23	12.16
K	Udu	8.61	16.14
L	Ewvreni	10.42	11.08
	Total	165.2	177.1

Source: Field Survey, 2011

Mean Soil Properties under Yam Cultivated Plots.

	Locations	pH	OC	Mg	Na	K	Ca	P	N	CEC
A	Akwukwu-Igbo	5.30	4.17	3.41	0.24	0.11	0.15	7.12	0.42	3.6
B	Ubulu-Ukwu	4.92	4.07	3.42	0.03	0.31	0.20	5.9	0.38	3.4
C	Emu-Uno	4.73	1.09	2.75	0.23	0.08	0.48	6.1	0.16	3.2
D	Okpai	4.46	3.88	3.71	0.26	0.09	0.27	6.2	0.24	2.8
E	Aradhe	5.0	4.38	2.02	0.30	0.12	0.13	7.4	0.46	3.1
F	Oleh	4.68	1.14	3.40	0.36	0.08	0.14	7.6	0.6	2.2
G	Otor-Owhe	3.35	4.95	1.07	0.47	0.42	0.08	3.6	0.12	2.6
H	Ubeji	5.26	3.80	0.92	0.03	0.23	0.05	2.1	0.8	2.8
I	Agbarho	4.7	0.22	2.91	0.31	0.30	0.07	3.6	0.2	2.7

J	Udu	4.8	1.8	2.2	0.2	0.2	0.2	4.3	0.30	2.7
K	Oghara	4.8	2.6	2.6	0.2	0.1	0.2	4.8	0.2	2.7
L	Ewvreni	4.8	2.8	2.8	0.2	0.5	0.2	4.9	0.2	2.8
	Mean	56.8	34.9	30.8	24.2	2.54	2.17	63.6	4.08	34.6

Source: Field Survey, 2011.

Mean Soil Properties under Cassava Cultivated Plots.

	Locations	pH	OC	Mg	Na	K	Ca	P	N	CEC
A	Akwukwu-Igbo	5.0	4.3	3.2	0.16	0.25	0.19	6.93	0.49	3.1
B	Ubulu-Ukwu	4.6	4.2	2.9	0.14	0.15	0.14	5.4	0.48	3.7
C	Emu-Uno	4.0	1.5	2.3	0.10	0.12	0.19	5.6	0.15	2.8
D	Okpai	4.9	4.0	3.1	0.24	0.16	0.36	6.8	0.33	3.3
E	Aradhe	5.2	1.9	3.3	0.28	0.12	0.56	7.1	0.36	2.9
F	Oleh	4.9	1.1	3.1	0.2	0.2	0.2	7.1	0.2	2.2
G	Otor-Owhe	5.2	4.2	1.4	0.2	0.3	0.1	3.4	0.6	2.3
H	Ubeji	4.9	3.6	1.6	0.11	0.2	0.2	2.9	0.4	2.4
I	Agbarho	4.9	1.0	1.5	0.3	0.3	0.2	3.4	0.1	2.5
J	Udu	4.13	0.39	2.69	0.6	0.22	0.14	5.81	0.36	3.10
K	Oghara	4.07	1.15	3.19	0.9	0.08	0.25	6.32	0.21	2.12
L	Ewvreni	4.06	2.82	3.40	0.12	0.16	0.18	6.18	0.28	2.46

	Mean	55.8	30.2	31.7	3.35	2.26	2.71	66.9	3.96	32.9

Source: field survey, 2011.

SPSS OUTPUT FOR MULTIPLE REGRESSION

Description Statistics

		Mean	Std. Deviation	N
Cassava		**4,1178**	**1.30043**	**9**
pH		**4.8633**	**.24469**	**9**
OC		**4.1400**	**2.36756**	**9**
Mg		**2.5333**	**.78337**	**9**
K		**.1933**	**.09233**	**9**
Na		**.1967**	**.09028**	**9**
Ca		**.2056**	**.12650**	**9**
P		**3.1200**	**.3642**	**9**
N		**2.5133**	**2.76864**	**9**
CEC		**.2067**	**.12876**	**9**

Correlations

	Cassava	pH	OC	Mg	K	Na	Ca	P	N	CEC
Pearson Correlation Cassava	**1.000**	**.074**	**-.190**	**-.678**	**.357**	**-.481**	**-.620**	**-.187**	**-.583**	**-.236**
pH	**0.74**	**1.00**	**.276**	**-.026**	**.126**	**.530**	**.293**	**-.026**	**.276**	**.126**
OC	**-.190**	**.276**	**1.00**	**-.180**	**.412**	**,360**	**-.384**	**.126**	**-.180**	**-.384**
Mg	**-.678**	**-.026**	**-.180**	**1.00**	**-.464**	**-.092**	**.570**	**.412**	**-.464**	**.412**

	K	.357	.126	.412	-.464	1.000	-.018	-.600	-.464	.412	.570
	Na	-.481	.530	.360	-.092	-.018	1.000	.444	-.180	.360	.444
	Ca	-.620	.293	-.384	.570	-.600	.444	1.00	.360	.126	.360
	P	-.187	.231	2.34	.360	.412	.530	-.018	1.00	.293	.530
	N	-.583	.222	4.12	.293	-.384	.126	-.092	-.384	1.00	.293
	CEC	-.561	.392	-.018	.530	.360	.293	.412	.276	.444	1.00
Sig. (1-tailed)	Cassava	.	.425	.312	.022	.173	.095	0.37	.292	.334	.186
	pH	.425	.	.236	.437	.374	.071	.222	.473	.236	.312
	OC	.312	.236	.	.321	.135	.171	.154	.374	.321	.425
	Mg	.022	.473	.321	.	.104	.407	.054	.135	.135	.321
	K	.173	.374	.135	.104	.	.482	.044	.071	.104	.473
	Na	.095	.071	.171	.407	.482	.	.116	.222	.321	.171
	Ca	.037	.222	.154	.054	.044	.116	.	.407	.022	.071
	P	.292	.228	.336	.374	.104	.104	.071	.	.374	.222
	N	.334	.341	.236	.236	.171	.135	.171	.154	.	.044
	CEC	.186	.381	.321	.154	.135	.071	.236	.037	.173	.
N	Cassava	9	9	9	9	9	9	9	9	9	9
	pH	9	9	9	9	9	9	9	9	9	9
	OC	9	9	9	9	9	9	9	9	9	9
	Mg	9	9	9	9	9	9	9	9	9	9
	K	9	9	9	9	9	9	9	9	9	9
	Na	9	9	9	9	9	9	9	9	9	9
	Ca	9	9	9	9	9	9	9	9	9	9
	P	9	9	9	9	9	9	9	9	9	9
	N	9	9	9	9	9	9	9	9	9	9
	CEC	9	9	9	9	9	9	9	9	9	9

SPSS OUTPUT FOR MULTIPLE REGRESSION

Description Statistics

	Mean	Std. Deviation	N
Yam	4.6578	2.0058	9
pH	4.8633	.24469	9
OC	4.1400	2.36956	9
Mg	2.5333	.78337	9
K	.1933	.09233	9
Na	.1967	.09028	9
Ca	.2056	.12650	9
P	4.6230	2.43682	9
N	3.8862	1.68324	9
CEC	.2943	.38442	9

Correlations

		Yam	pH	OC	Mg	K	Na	Ca	P	N	CEC
Pearson Correlation	Yam	1.000	.322	.518	-.019	-.313	.379	-.021	.426	-.381	-.129
	pH	-.322	1.00	.276	-.026	-.126	.530	.293	.530	.322	-.018
	OC	-.518	.276	1.00	-.018	.412	.360	.384	.412	.026	.384
	Mg	-.019	.026	-.180	1.00	-.464	-.992	.570	.180	.313	.412

	K	-.313	.126	.412	-.464	1.000	-.018	.600	.026	.180	-.092
	Na	-.379	.530	.360	-.092	-.018	1.000	.444	.530	.018	-.600
	Ca	-.021	.293	.384	-.570	-.600	.444	1.00	.293	.360	.092
	P	.426	.426	.018	.530	.444	.092	.313	1.00	0.29	.313
	N	.381	.412	.530	.412	.412	.276	.293	.021	1.00	.021
	CEC	.1288	.379	.444	.23	.600	.381	.360	.426	0.239	1.00
Sig. (1-tailed)	Yam	.	.199	.076	.481	.206	.157	.479	.031	.544	.326
	pH	.199	.	,236	.473	.374	.374	.222	.135	.135	.166
	OC	.076	.236	.	.321	.135	.135	.154	.437	.104	.321
	Mg	.481	.473	321	.	.104	.104	.054	.321	.482	.473
	K	.026	.374	.135	.104	.	.	.044	.104	.497	.171
	Na	.157	.071	.171	.407	.482	482	.	.171	.044	.071
	Ca	.479	.222	.154	.054	.044	.044	.166	.	.154	.374
	P	.081	.154	.104	.479	.104	.166	.321	071	.	.135
	N	.054	.104	.407	.044	.135	.199	.071	.154	.479	.
	CEC	.362	.374	.054	.135	.071	.157	.104	.054	.171	.473
N	Yam	9	9	9	9	9	9	9	9	9	9
	pH	9	9	9	9	9	9	9	9	9	9
	OC	9	9	9	9	9	9	9	9	9	9
	Mg	9	9	9	9	9	9	9	9	9	9
	K	9	9	9	9	9	9	9	9	9	9
	Na	9	9	9	9	9	9	9	9	9	9
	Ca	9	9	9	9	9	9	9	9	9	9
	P	9	9	9	9	9	9	9	9	9	9
	N	9	9	9	9	9	9	9	9	9	9
	CEC	9	9	9	9	9	9	9	9	9	9

Model summary

Model	R	r. square	Adjusted R square	Std. error of the estimated	Change characteristics				
I	.933a	.986	.944	.47446	.986	23.376	6	2	.042

a. Predictor (Consonants) Ca, pH, OC, Mg, K, Na, P, N, CEC

ANOVA

Model	Sum of square	Df	Mean Square	F	Sig
1 Regression	31.568	6	5.261	23.372	.042a
Residual	.450	2	.255		
Total	32.019	8			

a. Predictor (Consonants) Ca, pH, OC, Mg, K, Na, P, N, CEC

b. Dependant Variable: Yam

Coefficients

Model		Unstandardized coefficient		Standardized coefficient	t	Sig.
		B	Std. Error	Beta		
1	(constant)	31.234	3.981	-.701	7.847	.016
	pH	-5.731	.874	.772	-6.554	.022
	OC	.652	.121	-1.33	5.373	.033
	Mg	-.339	.350	-.598	-.969	.435
	K	.12.968	2.523	.450	-5.141	.036
	Na	9.982	3.627	-.003	2.752	.111
	Ca	-.040	3.489	.687	-.011	.992
	P	.568	1.226	.571	4.632	0.31
	N	.472	1.18	-.624	3.811	0.26
	CEC	-8.886	3.468		-6.49	0.048s

Model summary

Model	R	r. square	Adjusted R square	Std. error of the estimated	Change characteristics				
I	.997	.993	.947	.21167	.993	49.993	6	2	.020

a. Predictor (Consonants) Ca, pH, OC, Mg, K, Na, P, N, CEC

ANOVA

Model		Sum of square	Df	Mean Square	F	Sig
1	Regression	13.439	6	2.240	49.993	.020
	Residual	.090	2	.045		
	Total	13.529	8			

a. Predictor (Consonants) Ca, pH, OC, Mg, K, Na, P, N, CEC
b. Dependant Variable: Cassava

Coefficients

Model		Unstandardized coefficient		Standardized coefficient	t	Sig.
		B	Std. Error	Beta		
2	(constant)	-5.095	1.776	.-.585	-.2868	.103
	pH	3.111	.390	-.438	7.974	.015
	OC	-.241	.054	-.541	-4.446	.047
	Mg	-.898	.156	-.100	-5.746	.029
	K	-1.406	1.125	-.459	-1.250	.338
	Na	-6.608	1.618	-.508	-4.083	.055

Ca	**-5.221**	**1.557**	**-.412**	**-3.54**	**.079**
P	**-.232**	**0.51**	**-.332**	**-4.221**	**.042**
N	**-.196**	**0.36**	**-.210**	**-3.646**	**.037**
CEC	**-.244**	**2.142**		**-2.430**	**.486**

APPENDIX V

Data for Hypothesis four

Soil Properties under Different Soil Management Methods.

Mean Yield of Yam (in Tons/He) under different Soil Management Methods in Delta State.

Locations	Fallow plot	Slash and burn plot	Tillage plot	Soil amendments	Total yield kg/ha.
A- Akwukwu-Igbo	5.22	4.04	3.04	4.06	16.36
B- Ubulu-Ukwu	4.10	3.26	3.18	3.48	14.02
C- Emu-Uno	4.81	2.14	2.23	3.10	12.28
D- Okpai	5.62	3.46	3.20	4.86	17.14
E- Aradhe	3.14	2.04	2.10	2.86	10.14
F- Oleh	6.92	4.52	4.66	5.96	22.06
G- Otor-Owhe	3.10	2.02	2.06	2.34	9.52
H- Ubeji	4.78	2.11	2.20	3.10	12.19
I- Agbarho	6.02	3.58	3.48	5.12	18.20
J- Oghara	4.16	3.31	3.23	3.53	14.23
K- Udu	2.41	2.02	2.06	2.12	8.61
L-Ewvreni	3.24	2.04	2.06	3.08	10.42
Total	53.52	33.52	33.5	44.61	165.2

Field Survey, 2011

Mean Yield of Cassava (in Tons/He) under different Soil Management Methods in Delta State.

Locations	Fallow plot	Slash and burn plot	Tillage plot	Soil amendments	Total yield kg/ha.
A- Akwukwu-Igbo	4.17	3.32	3.23	3.54	14.26
B- Ubulu-Ukwu	6.02	3.52	3.41	5.08	18.03
C- Emu-Uno	3.18	2.09	2.13	2.41	9.81
D- Okpai	4.76	2.14	2.26	3.07	12.23
E- Aradhe	3.14	2.08	2.12	2.86	10.20
F- Oleh	4.10	3.26	3.20	3.48	14.04
G- Otor-Owhe	7.96	4.52	4.46	6.88	24.02
H- Ubeji	6.14	4.47	4.31	5.12	20.04
I- Agbarho	2.80	2.03	2.05	2.24	9.12
J- Oghara	4.75	2.10	2.18	3.13	12.16
K- Udu	5.62	3.46	3.20	3.86	16.14
L-Ewvreni	3.65	2.37	2.35	3.43	11.08
Total	56.29	35.36	35.11	45.1	177.1

Field Survey, 2011

SPSS OUTPUT FOR MULTIPLE REGRESSION

Description Statistics

	Mean	Std. Deviation	N
Soil properties	13.6807	27.43986	14
Fallowing	12.9050	26.77830	14
Slash and burn	11.7629	25.65810	14
Tillage	12.2064	26.44353	14
Soil amendments	12.4059	26.53221	14

Correlation

	Soil properties	Fallowing	Slash and burn	Tillage	Soil amendments
Person Correlation Soil properties	1.000	.999	.999	.999	.999
Fallowing	.999	1 .000	.999	.999	.999
Slash and burn	.999	.999	1.000	.999	.999
Tillage	.999	.999	.999	1.000	.999
Soil amendments	.999	.999	.999	.999	1.000
Sig. (t-tailed) Soil properties	.	.000	.000	.000	.000
Fallowing	.000	.	.000	.000	.000
Slash and burn	.000	.000	.	.000	.000
	.000	.000	.000	.	.000
	.000	.000	.000	000	.

	Tillage Soil amendments					
N	Soil properties	14	14	14	14	14
	Fallowing	14	14	14	14	14
	Slash and burn	14	14	14	14	14
	Tillage	14	14	14	14	14
	Soil amendments	14	14	14	14	14

Model summary

Model	R	R Square	Adjusted R square	Std. Error of the estimate	Change statistics				
					R.Square Change	F Change	df 1	dt 2	Sig. F Change
1	.999	.999	.999	1.06184	.999	.2890.464	3	10	.000

a. Predictors (Constant) Tillage, Fallowing, Slash and Burn, Soil Amendments

Model	Sum of squares	Df	Mean Square	F	Sig
1 Regression	9777.025	3	3259.008	2890.464	.000*
Residual	11.275	10	1.128		
Total	9788.300	13			

a. Predictor (Constant), Tillage, Fallowing, Slash and burn, Soil amendments

b. Dependable Variable: Soil properties

Coefficient

Model	Unsterdadised Coefficient		Standadised Cofficient	T	Sig	Correlation		
	B	Std. Error				Zero order	Partial	part

1 Constant	.640	.347		1.847	.094			
Fallowing	.732	.261	.714	2.801	.019	.999	.663	.030
Slash and burn	.247	.547	.231	.451	.661	.999	.141	.005
Tillage	.057	.627	.054	.090	.930	.999	.029	.001
Amendments	.532	.361	.620	1.036	.042	.999	.461	.016

Appendix VI

ANALYSIS OF VARIANCE (ANOVA) OF YAM AND CASSAVA YIELD AMONG THE THREE REGIONS OF DELTA STATE

S/N	DN	DC	DS	(Dn – x)^2	(Dc- x)^2	(Ds-x)^2
1	16.36	10.14	18.20	2.1	5.0	5.7
2	14.02	22.06	14.23	0.3	6.8	1.7
3	12.28	9.52	8.61	1.9	5.8	3.9
4	17.14	12.19	10.42	2.9	3.1	2.1
5	14.26	10.20	9.12	0.1	5.1	3.4
6	18.03	14.04	12.16	3.8	1.2	0.3
7	9.81	24.02	16.14	4.5	8.6	3.7
8	12.23	20.04	11.08	2.0	4.8	1.4
X	14.27	15.27	12.49	17.6	40.4	22.2

DN - Delta North DC – Delta Central DS - Delta South

SPSS OUPUT

One Way

Description

	N	**Mean**	**Std. Deviations**	**Std. Error**	**Upper Bound**	**Lower Bound**	**Min.**	**Max.**
1. DN	8	14.27	8.10561	2.03607	6.5101	15.0334	0.01	32.45
2. DC	8	15.27	10.3242	6.10174	4.0002	75.4418	0.23	318.72
3. DS	8	12.49	6.6528	11.06614	5.0760	22.2460	0.48	77.52
TOTAL	24	42.03	43.3236	10.43309	62.1417	62.1417	0.01	500.00

Test of Homogenity of Varience

Levene Statistics	df1	df2	Sig.
10.431	**7**	**48**	**0.000**

ANOVA

	Sum of Squares	df	Variance	F	Sig.
Between Groups	64599.2	7	2.62807	7.526	0.005
Within Groups	**27599.04**	**2**	**2.75981**		
Total	**688035.06**	**9**			

Appendix VII

Monthly Soil Properties Data under Deforested Plots In January

Soil Properties	A	B	C	D	E	F	G	H	I	J	K	L
Sand %	90.4	89.8	95.3	89.1	90.5	89.9	85.6	84.2	89.3	88.2	85.8	90.6
Silt %	7.1	4.3	6.8	6.4	4.4	3.9	4.5	6.4	11.8	4.9	4.6	6.2
Clay %	2.8	2.6	4.5	2.6	2.6	6.0	4.5	3.7	4.9	2.8	4.5	3.4
Bulk Density	1.41	1,43	1.43	1.29	1.40	1.30	0.73	1.04	1.19	1.41	1.29	1.36
Total Porosity	63.0	66.24	62.83	63.13	66.44	63.05	60.74	59.49	60.4	64.8	62.82	60.91
Soil pH (in water)	5.30	4.92	4.73	4.64	5.00	4.68	5.35	5.26	4.7	5.28	4.86	4.71
Organic carbon %	4.17	4.06	1.09	3.88	4.38	1.14	4.45	3.80	0.22	1.56	4.12	3.22
Total Nitrogen %	0.54	0.35	0.30	0.30	0.35	0.21	0.51	0.70	0.20	0.36	0.31	0.28

Available Phosphorous	6.42	6.69	4.62	5.69	7.57	7.39	2.98	4.66	3.13	5.81	6.32	6.18
CEC	0.96	4.04	3.60	2.76	3.19	2.11	2.11	2.00	0.33	3.10	2.12	2.46
Magnesium	3.41	3.24	2.75	3.71	2.02	3.40	1.07	0.92	2.91	1.15	3.51	2.66
Potassium	0.11	0.31	0.08	0.09	0.12	0.08	0.42	0.23	0.30	0.09	0.12	0.22
Sodium	0.24	0.03	0.23	0.26	0.30	0.36	0.47	0.03	0.31	0.22	0.08	0.27
Calcium	0.15	0.20	0.48	0.27	0.13	0.14	0.08	0.05	0.07	0.16	0.28	0.20

Source of Data: Field survey, 2010

Locations: A- Akwukwu-Igbo, B- Ubulu-Ukwu, C- Emu-Uno, D- Okpai, E- Aradhe, F- Oleh, G- Otor- Owhe H- Ubeji I- Agbarho, J- Udu, K- Oghara, L- Ewvreni

Monthly Soil Properties Data under Deforested Plots In February

Soil Properties	A	B	C	D	E	F	G	H	I	J	K	L
Sand %	89.8	86.9	89.3	90.9	86.5	90.9	86.1	83.7	93.2	90.6	88.8	86.9
Silt %	7.0	3.2	6.9	6.5	3.5	3.7	4.1	12.6	8.6	4.6	6.2	3.5
Clay %	2.6	5.6	4.2	2.9	5.6	6.4	5.0	5.6	2.8	5.4	2.8	4.2
Bulk Density	1.41	1.38	1.41	1.28	1.19	1.21	0.81	1.04	1.15	1.26	1.44	1.18
Total Porosity	63.0	61.5	63.3	63.4	60.5	63.1	60.6	65.3	50.2	63.1	64.8	60.9
Soil pH (in water)	5.30	4.50	4.30	4.70	5.27	4.76	5.84	4.25	5.63	4.20	4.66	5.21
Organic carbon %	4.17	9.43	1.15	3.84	1.37	1.12	4.54	4.61	0.25	1.15	2.82	3.16
Total Nitrogen %	0.54	0.62	0.24	0.36	0.41	0.21	0.49	0.38	0.16	0.30	0.28	0.41
Available Phosphorous	6.42	4.72	4.21	5.77	6.49	7.31	2.54	1.26	1.54	6.12	4.38	4.54
CEC	0.96	3.68	3.74	2.98	2.78	2.08	2.08	3.20	3.0	2.84	3.09	3.62

Magnesium	3.41	3.20	2.57	3.78	3.51	3.35	1.34	1.15	3.40	1.66	2.67	3.11
Potassium	0.11	0.13	0.13	0.12	0.07	0.09	0.25	0.14	0.28	0.12	0.08	0.24
Sodium	0.24	0.08	0.22	0.27	0.27	0.35	0.28	0.08	0.39	0.16	0.22	0.16
Calcium	0.15	0.09	0.14	0.29	0.01	0.12	0.07	0.26	0.09	0.08	0.14	0.28

Source of Data: Field survey, 2010

Locations: A- Akwukwu-Igbo, B- Ubulu-Ukwu, C- Emu-Uno, D- Okpai, E- Aradhe, F- Oleh, G- Otor- Owhe H- Ubeji I- Agbarho, J- Oghara, K- Udu, L- Ewvreni

Monthly Soil Properties Data under Deforested Plots In March

Soil Properties	A	B	C	D	E	F	G	H	I	J	K	L
Sand %	90.3	88.1	84.6	91.2	86.2	84.2	84.6	91.1	90.4	86.4	90.2	88.2
Silt %	7.3	3.6	6.2	6.0	3.9	6.7	7.8	10.3	3.21	6.0	4.9	6.1
Clay %	2.5	5.4	9.7	3.4	5.4	6.5	8.5	5.4	3.0	8.2	4.4	5.6
Bulk Density	1.50	1.39	1.44	1.08	1.30	1.19	1.82	1.62	1.4	1.07	1.20	1.32
Total Porosity	61.6	61.3	59.9	63.7	60.9	59.01	60.5	49.3	63.5	62.5	60.9	58.6
Soil pH (in water)	4.97	4.38	4.23	4.84	5.32	5.04	5.74	5.22	4.32	5.14	4.32	4.06
Organic carbon %	4.09	3.39	1.40	3.80	1.36	0.68	4.61	4.73	1.27	2.18	3.10	2.56
Total Nitrogen %	0.48	0.60	0.08	0.34	0.44	0.13	0.52	0.52	0.12	0.38	0.41	0.32
Available Phosphorous	6.28	4.81	5.47	5.98	6.59	6.77	2.65	2.43	3.85	3.12	4.58	3.66
CEC	1.01	3.59	2.12	3.84	2.82	2.14	2.14	1.60	2.00	1.64	2.72	2.38
Magnesium	3.19	3.05	2.14	3.69	3.63	3.01	1.12	1.17	0.98	2.69	3.08	3.21
Potassium	0.21	0.16	0.06	0.11	0.08	0.14	0.21	0.21	0.21	0.10	0.12	0.20
Sodium	0.21	0.09	0.01	0.29	0.29	0.12	0.35	0.03	0.35	0.36	0.16	0.09

Calcium	0.17	0.12	0.19	0.30	0.99	0.19	0.06	0.29	0.18	0.14	0.25	0.18

Source of Data: Field survey, 2010
Locations: A- Akwukwu-Igbo, B- Ubulu-Ukwu, C- Emu-Uno, D- Okpai,
E- Aradhe, F- Oleh, G- Otor- Owhe H- Ubeji I- Agbarho, J- Oghara,
K- Udu, L- Ewvreni

Monthly Soil Properties Data under Deforested Plots In April

Soil Properties	A	B	C	D	E	F	G	H	I	J	K	L
Sand %	88.4	88.3	83.2	90.0	86.3	84.4	87.9	73.8	84.5	86.2	84.9	88.4
Silt %	7.4	3.1	5.8	5.9	3.8	6.9	8.1	9.6	2.61	4.7	5.2	3.9
Clay %	2.9	6.3	9.8	3.1	6.3	7.9	8.0	6.3	5.7	5.4	4.9	6.6
Bulk Density	1.42	1.42	1.40	1.35	1.46	1.28	1.71	1.41	1.62	1.35	1.40	1.31
Total Porosity	64.18	60.93	60.12	63.63	60.60	59.11	60.12	54.65	60.54	64.20	60.18	58.20
Soil pH (in water)	5.24	4.61	4.25	4.70	5.30	5.0	5.20	5.75	5.10	5.06	4.81	5.50
Organic carbon %	4.21	4.51	1.32	3.90	1.33	0.61	4.41	4.81	1.29	1.47	2.18	3.23
Total Nitrogen %	0.50	0.59	0.07	0.34	0.39	0.08	0.45	0.42	0.13	0.19	0.32	0.38
Available Phosphorous	6.34	4.70	5.82	6.18	6.68	6.92	2.68	3.41	3.10	2.81	3.70	2.62
CEC	10.3	3.70	2.11	2.90	2.88	2.18	2.18	2.00	2.90	2.86	2.40	3.10
Magnesium	3.16	3.40	2.06	3.77	3.48	3.01	2.65	2.03	0.92	3.19	2.96	3.40
Potassium	0.24	0.12	0.07	0.12	0.06	0.16	0.12	0.18	0.29	0.22	0.08	0.16
Sodium	0.16	0.06	0.01	0.22	0.33	0.17	0.25	0.10	0.29	0.22	0.08	0.11
Calcium	0.15	0.10	0.20	0.26	1.10	0.24	0.10	0.32	0.16	0.14	0.18	0.09

Source of Data: Field survey, 2010
Locations: A- Akwukwu-Igbo, B- Ubulu-Ukwu, C- Emu-Uno, D- Okpai,

E- Aradhe, F- Oleh, G- Otor- Owhe H- Ubeji I- Agbarho, J- Udu,
K- Oghara, L- Ewvreni

Monthly Soil Properties Data under Deforested Plots In May

Soil Properties	A	B	C	D	E	F	G	H	I	J	K	L
Sand %	91.1	86.2	83.2	90.9	86.1	84.7	90.3	69.12	89.3	88.2	90.6	86
Silt %	7.2	3.7	5.9	6.2	3.0	6.9	8.5	13.20	3.7	4.5	6.2	4.9
Clay %	3.2	5.7	9.4	3.5	5.7	5.6	6.5	5.3	6.5	5.6	3.8	4.2
Bulk Density	1.43	1.40	1.39	1.40	1.38	1.32	1.43	1.23	1.21	1.36	1.28	1.2
Total Porosity	63.5	61.9	60.10	63.72	60.56	59.30	63.35	60.07	65.24	62.8	60.12	60
Soil pH (in water)	5.60	4.37	4.30	4.72	5.34	4.96	4.67	5.06	4.46	4.60	4.22	4.6
Organic carbon %	4.26	4.44	1.46	3.88	1.30	0.65	4.59	4.61	1.34	2.88	2.46	3.1
Total Nitrogen %	0.37	0.58	0.05	0.36	0.42	0.10	0.68	0.35	0.14	0.21	0.11	0.2
Available Phosphorous	6.32	4.69	4.94	6.08	6.66	6.69	2.65	1.41	4.41	4.69	6.14	6.0
CEC	0.95	3.71	2.10	2.82	2.85	2.12	2.12	3.20	3.30	3.52	2.22	2.2
Magnesium	3.12	3,07	2.16	3.73	3.51	3.06	1.30	1.06	0.78	1.12	2.16	3.0
Potassium	0.15	0.11	0.05	0.11	0.10	0.10	0.35	0.12	0.38	0.26	0.12	0.1
Sodium	0.25	0.08	0.01	0.26	0.32	0.14	0.33	0.05	0.36	0.32	0.28	0.2
Calcium	0.15	0.13	0.17	0.28	1.02	0.22	0.09	0.32	0.17	0.16	0.12	0.2

Source of Data: Field survey, 2010

Locations: A- Akwukwu-Igbo, B- Ubulu-Ukwu, C- Emu-Uno, D- Okpai,
E- Aradhe, F- Oleh, G- Otor- Owhe H- Ubeji I- Agbarho, J- Oghara,
K- Udu, L- Ewvreni

Monthly Soil Properties Data under Deforested Plots In June

Soil Properties	A	B	C	D	E	F	G	H	I	J	K	L
Sand %	92.8	89.0	89.7	84.7	93.5	86.5	88.4	80.9	90.4	89.0	90.1	88.7
Silt %	4.2	3.4	6.4	3.9	3.8	7.0	4.9	12.9	3.2	4.4	5.2	3.8
Clay %	2.5	6.0	9.5	2.8	6.0	5.4	4.8	6.5	7.3	5.6	4.8	6.1
Bulk Density	1.36	1.46	1.50	1.36	1.37	1.33	1.18	1.35	1.89	1.41	1.26	1.32
Total Porosity	65.19	62.33	59.0	65.41	60.54	58.18	67.57	50.87	58.3	60.15	61.34	58.40
Soil pH (in water)	4.70	4.59	4.21	5.0	5.32	5.02	5.2	5.32	4.50	4.81	4.07	4.26
Organic carbon %	3.70	4.48	1.29	4.16	1.39	0.21	3.21	4.69	1.36	1.21	0.36	1.42
Total Nitrogen %	0.32	0.66	0.09	0.33	0.44	0.12	0.63	0.48	0.11	0.34	0.11	0.36
Available Phosphorous	6.80	4.78	4.90	7.57	6.98	6.94	3.1	1.21	3.18	3.22	3.16	4.08
CEC	4.20	3.45	2.09	3.36	2.87	2.12	2.12	2.65	2.0	3.20	2.86	2.21
Magnesium	3.36	3.34	2.10	2.01	3.58	3.07	1.30	1.32	0.82	1.46	0.92	1.38
Potassium	0.29	0.18	0.09	0.10	0.07	0.11	0.24	0.20	0.41	0.26	0.14	0.22
Sodium	0.03	0.09	0.01	0.26	0.34	0.12	0.06	0.09	0.28	0.06	0.18	0.20
Calcium	0.22	0.11	0.16	0.13	1.08	0.25	0.07	0.35	0.14	0.19	0.16	0.44

Source of Data: Field survey, 2010

Locations: A- Akwukwu-Igbo, B- Ubulu-Ukwu, C- Emu-Uno, D- Okpai, E- Aradhe, F- Oleh, G- Otor- Owhe H- Ubeji I- Agbarho, J- Oghara, K- Udu, L- Ewvreni

Monthly Soil Properties Data under Deforested Plots in July

Soil Properties	A	B	C	D	E	F	G	H	I	J	K	L
Sand %	93.4	89.2	84.9	93.8	89.4	84.1	89.1	89.7	97.2	92.8	88.1	89.4
Silt %	4.1	6.5	6.2	3.10	3.9	7.1	5.9	12.5	2.3	3.6	3.1	4.2
Clay %	2.1	3.4	9.6	2.7	6.1	6.3	3.2	2.4	2.5	2.8	3.1	2.9
Bulk Density	1.39	1.32	1.42	1.41	1.19	1.22	1.10	1.21	1.32	1.26	1.34	1.20
Total Porosity	65.40	62.70	56.97	64.49	62.67	59.19	69.04	69.44	62.72	66.30	58.49	62.19
Soil pH (in water)	4.62	4.91	4.31	5.06	4.69	5.08	4.63	4.35	5.12	4.18	5.62	4.71
Organic carbon %	3.95	1.18	1.38	4.30	1.10	0.65	3.47	0.24	1.37	0.88	1.42	1.20
Total Nitrogen %	0.39	0.26	0.06	0.25	0.19	0.12	0.67	0.13	0.15	0.16	0.24	0.13
Available Phosphorous	6.9	4.41	5.92	7.60	7.27	7.04	2.95	3.21	3.16	3.41	4.8	5.04
CEC	4.09	3.74	2.13	3.39	2.49	2.08	2.08	0.65	2.65	3.09	2.78	2.31
Magnesium	3.19	2.66	2.69	2.16	3.40	3.05	0.94	1.32	0.80	1.29	2.66	3.19
Potassium	0.28	0.10	0.08	0.19	0.08	0.13	0.19	0.20	0.31	0.19	0.11	0.22
Sodium	0.03	0.19	0.01	0.24	0.31	0.11	0.02	0.09	0.35	0.06	0.09	0.26
Calcium	0.22	0.19	0.18	0.12	0.11	0.25	0.05	0.35	0.18	0.21	0.14	0.10

Source of Data: Field survey, 2010
Locations: A- Akwukwu-Igbo, B- Ubulu-Ukwu, C- Emu-Uno, D- Okpai,
E- Aradhe, F- Oleh, G- Otor- Owhe H- Ubeji I- Agbarho, J- Oghara,
K- Udu, L- Ewvreni

Monthly Soil Properties Data under Deforested Plots In August

Soil Properties	A	B	C	D	E	F	G	H	I	J	K	L

Sand %	91.9	90.4	89.3	91.1	88.7	90.9	95.9	87.3	93.2	90.6	91.2	88.6
Silt %	4.6	6.9	6.9	3.	3.8	3.7	7.8	10.2	8.6	5.4	4.9	5.8
Clay %	2.8	3.5	4.2	2.4	6.6	6.4	2.8	3.3	2.8	3.6	4.1	2.9
Bulk Density	1.29	1.38	1.41	1.29	1.34	1.21	0.99	1.38	1.15	1.26	1.31	1.26
Total Porosity	65.02	61.91	63.26	65.57	62.91	63.07	68.49	70.05	50.21	62.04	60.81	58.2
Soil pH (in water)	4.91	4.62	4.30	4.98	4.81	5.04	4.06	5.12	5.63	5.19	4.82	4.96
Organic carbon %	4.21	1.17	1.15	4.20	1.04	0.68	3.51	0.23	0.25	2.37	3.20	1.60
Total Nitrogen %	0.41	0.21	0.24	0.29	0.16	0.13	0.70	0.19	0.16	0.38	0.26	0.14
Available Phosphorous	7.01	4.40	4.21	7.72	7.32	6.77	4.02	2.33	1.54	2.40	3.86	2.88
CEC	4.14	3.68	3.74	3.19	2.60	2.33	2.33	2.00	1.60	1.88	2.61	3.16
Magnesium	3.41	2.61	2.57	2.04	3.40	3.01	1.21	3.24	3.40	2.41	2.21	3.14
Potassium	0.19	0.11	0.13	0.11	0.07	0.14	0.29	0.36	0.28	0.21	0.14	0.11
Sodium	0.04	0.48	0.22	0.26	0.34	0.12	0.07	0.32	0.39	0.08	0.36	0.32
Calcium	0.18	0.18	0.14	0.17	0.13	0.19	0.09	0.10	0.09	0.17	0.12	0.14

Source of Data: Field survey, 2010
Locations: A- Akwukwu-Igbo, B- Ubulu-Ukwu, C- Emu-Uno, D- Okpai, E- Aradhe, F- Oleh, G- Otor- Owhe H- Ubeji I- Agbarho, J- Oghara, K- Udu, L- Ewvreni

Monthly Soil Properties Data under Deforested Plots In September

Soil Properties	A	B	C	D	E	F	G	H	I	J	K	L
Sand %	93.1	89.1	84.6	92.9	90.7	84.2	92.4	94.1	90.4	92.2	86.4	89.8
Silt %	4.5	6.4	6.2	3.8	3.7	6.7	4.9	8.9	3.21	4.2	3.5	5.1
Clay %	2.8	3.8	9.7	2.5	6.4	8.1	4.6	5.1	3.0	2.9	3.2	4.6

Bulk Density	1.28	1.41	1.44	1.49	1.21	1.19	1.20	1.32	1.4	1.06	1.42	1.38
Total Porosity	66.90	62.83	59.08	65.34	64.07	59.02	60.91	50.30	63.5	60.90	61.84	58.34
Soil pH (in water)	4.40	4.84	4.23	5.04	4.66	5.00	4.89	4.85	4.32	4.13	4.54	4.33
Organic carbon %	4.08	1.11	1.40	4.36	1.11	0.61	3.41	0.26	1.29	1.38	1.16	2.40
Total Nitrogen %	0.43	0.19	0.08	0.33	0.18	0.08	0.37	0.17	0.12	0.17	0.36	0.20
Available Phosphorous	7.00	4.51	5.47	7.59	7.29	6.92	3.42	2.94	3.85	3.51	4.28	5.12
CEC	4.08	3.70	2.12	3.45	2.70	2.35	2.35	3.20	3.55	2.70	3.08	2.35
Magnesium	3.50	2.56	2.14	1.97	3.50	3.01	1.15	2.97	0.98	2.50	1.86	2.31
Potassium	0.23	0.08	0.06	0.18	0.08	0.16	0.15	0.34	0.31	0.28	0.14	0.08
Sodium	0.02	0.23	0.01	0.24	0.34	0.17	0.02	0.28	0.35	0.04	0.20	0.17
Calcium	0.20	0.16	0.19	0.15	0.10	0.24	0.04	0.11	0.18	0.20	0.15	0.12

Source of Data: Field survey, 2010
Locations: A- Akwukwu-Igbo, B- Ubulu-Ukwu, C- Emu-Uno, D- Okpai, E- Aradhe, F- Oleh, G- Otor- Owhe H- Ubeji I- Agbarho, J- Oghara, K- Udu, L- Ewvreni

Monthly Soil Properties Data under Deforested Plots In October

Soil Properties	A	B	C	D	E	F	G	H	I	J	K	L
Sand %	91.9	92.8	92.5	89.9	90.4	90.3	89.9	90.3	89.9	88.8	91.8	90.6
Silt %	9.2	8.6	4.9	3.8	3.6	3.4	3.4	2.5	2.6	3.8	4.6	3.2
Clay %	4.5	4.1	4.1	3.5	3.8	9.1	9.7	9.9	4.2	4.1	3.8	5.6
Bulk Density	1.36	1.36	1.33	1.30	1.29	1.30	1.17	1.20	1.42	1.38	1.36	1.32
Total Porosity	65.7	65.80	66.8	67.1	67.4	66.1	66.1	66.1	66.13	66.7	64.8	67.8

Soil pH (in water)	5.09	5.10	5.14	5.67	5.62	5.01	5.03	5.08	5.40	5.12	5.41	5.68
Organic carbon %	6.24	3.87	4.20	4.42	5.14	5.03	4.93	5.58	1.84	3.24	4.81	4.56
Total Nitrogen %	0.94	0.48	0.37	0.39	0.43	0.62	0.59	0.66	0.21	0.42	0.38	0.51
Available Phosphorous	11.03	11.3	11.54	9.88	9.86	8.76	8.92	8.89	7.72	10.02	9.72	8.93
CEC	4.50	4.3	4.04	3.81	4.91	3.93	3.86	3.98	3.16	3.52	4.1	3.68
Magnesium	2.37	2.27	2.17	2.47	2.22	2.10	2.04	2.17	2.11	2.22	2.18	2.34
Potassium	0.40	0.32	0.41	0.57	0.55	0.60	0.64	0.50	0.38	0.43	0.48	0.52
Sodium	0.33	0.26	0.32	0.03	0.02	0.11	0.06	0.10	0.13	0.31	0.28	0.12
Calcium	0.21	0.19	0.20	1.91	1.08	0.20	0.22	0.18	0.99	0.20	0.16	0.34

Source of Data: Field survey, 2010
Locations: A- Akwukwu-Igbo, B- Ubulu-Ukwu, C- Emu-Uno, D- Okpai, E- Aradhe, F- Oleh, G- Otor- Owhe H- Ubeji I- Agbarho, J- Oghara, K- Udu, L- Ewvreni

Monthly Soil Properties Data under Deforested Plots In November

Soil Properties	A	B	C	D	E	F	G	H	I	J	K	L
Sand %	90.8	87.9	88.3	89.9	86.5	90.9	86.1	83.7	92.2	88.8	90.2	82.6
Silt %	7.2	3.0	6.8	6.6	3.5	3.7	4.3	12.6	8.4	6.2	5.8	7.4
Clay %	2.9	5.3	4.5	2.6	5.6	6.4	5.4	5.4	2.6	3.4	4.9	5.2
Bulk Density	1.38	1.32	1.41	1.21	1.19	1.28	0.81	1.07	1.21	1.26	1.42	1.36
Total Porosity	61.5	63.4	63.3	63.0	60.5	63.1	50.2	65.3	60.6	62.6	60.5	60.2
Soil pH (in water)	5.41	4.39	4.30	5.84	5.27	4.76	4.70	4.22	5.66	5.48	4.91	5.86
Organic carbon %	4.19	1.15	3.84	9.41	1.37	1.12	4.54	4.59	0.27	0.39	2.46	3.72
Total Nitrogen %	0.68	0.50	0.22	0.36	0.41	0.21	0.49	0.36	0.18	0.48	0.26	0.20

Available Phosphorous	6.75	5.77	4.39	5.77	2.54	7.31	6.49	1.28	1.52	1.86	1.67	2.18
CEC	0.95	3.75	3.68	2.98	2.78	2.08	3.0	3.20	2.08	3.10	2.88	3.19
Magnesium	2.57	3.78	3.41	3.20	3.51	3.35	1.34	1.13	3.42	5.57	3.20	2.68
Potassium	0.14	0.10	0.13	0.11	0.08	0.09	0.25	0.16	0.26	0.18	0.12	0.20
Sodium	0.21	0.11	0.25	0.24	0.27	0.36	0.39	0.07	0.28	0.22	0.32	0.26
Calcium	0.14	0.29	0.15	0.09	0.01	0.12	0.09	0.26	0.07	0.12	0.18	0.08

Source of Data: Field survey, 2010

Locations: A- Akwukwu-Igbo, B- Ubulu-Ukwu, C- Emu-Uno, D- Okpai, E- Aradhe, F- Oleh, G- Otor- Owhe H- Ubeji I- Agbarho, J- Oghara, K- Udu, L- Ewvreni

Monthly Soil Properties Data Deforested Plots In December

Soil Properties	A	B	C	D	E	F	G	H	I	J	K	L
Sand %	91.2	84.2	91.1	90.3	86.2	88.1	90.4	84.6	84.6	90.6	88.1	86.8
Silt %	6.7	7.8	10.3	6.0	3.21	7.3	3.6	6.2	3.9	4.8	5.2	3.6
Clay %	3.4	8.5	5.4	2.5	5.4	3.0	5.4	9.7	6.5	5.4	6.2	5.8
Bulk Density	1.44	1.19	1.08	1.50	1.4	1.39	1.80	1.64	1.30	1.31	1.14	1.38
Total Porosity	61.8	60.9	59.9	63.5	61.3	59.01	63.5	49.3	60.5	62.8	58.9	60.5
Soil pH (in water)	4.84	5.74	4.23	4.97	4.32	5.04	4.38	5.22	5.32	5.28	4.86	5.06
Organic carbon %	3.80	1.27	0.68	4.09	1.36	1.40	4.64	4.70	3.39	3.62	4.06	3.10
Total Nitrogen %	0.44	0.52	0.12	0.30	0.48	0.13	0.12	0.60	0.52	0.30	0.41	0.26
Available Phosphorous	5.47	3.85	6.28	2.43	6.61	6.70	2.65	5.98	4.81	4.64	5.12	4.88

CEC	2.12	3.84	1.01	3.59	1.60	2.00	2.14	2.82	2.14	2.09	2.16	2.32
Magnesium	3.63	1.12	2.14	1.17	3.19	0.98	3.05	3.69	3.01	3.09	3.20	2.96
Potassium	0.06	0.16	0.21	0.21	0.08	0.13	0.22	0.21	0.11	0.10	0.13	0.08
Sodium	0.29	0.09	0.01	0.21	0.29	0.35	0.35	0.03	0.12	0.22	0.14	0.20
Calcium	0.19	0.17	0.12	0.30	0.99	0.18	0.06	0.19	0.29	0.17	0.27	0.12

Source of Data: Field survey, 2010

Locations: A- Akwukwu-Igbo, B- Ubulu-Ukwu, C- Emu-Uno, D- Okpai, E- Aradhe, F- Oleh, G- Otor- Owhe H- Ubeji I- Agbarho, J- Oghara, K- Udu, L- Ewvreni

Appendix VII

Monthly Soil Properties Data under Forested Plots in January

Soil Properties	A	B	C	D	E	F	G	H	I	J	K	L
Sand %	91.9	92.8	92.5	89.9	90.4	90.3	89.9	90.3	89.9	88.8	91.4	89.3
Silt %	9.2	8.6	4.9	3.8	3.6	3.4	3.4	2.5	2.6	2.9	3.2	3.7
Clay %	4.5	4.1	4.1	3.5	3.8	9.1	9.7	9.9	4.2	4.1	4.4	4.6
Bulk Density	1.36	1.36	1.33	1.30	1.29	1.30	1.17	1.20	1.42	1.38	1.29	1.33
Total Porosity	65.7	65.80	66.8	67.1	67.4	66.1	66.1	66.1	66.13	66.8	66.2	67.4
Soil pH (in water)	5.09	5.10	5.14	5.67	5.62	5.01	5.03	5.08	5.40	5.15	5.21	5.32
Organic carbon %	6.24	3.87	4.20	4.42	5.14	5.03	4.93	5.58	1.84	2.36	3.48	4.10
Total Nitrogen %	0.94	0.48	0.37	0.39	0.43	0.62	0.59	0.66	0.21	0.42	0.36	0.39
Available Phosphorous	11.03	11.3	11.54	9.88	9.86	8.76	8.92	8.89	7.72	8.4	8.69	9.81
CEC	4.50	4.3	4.04	3.81	4.91	3.93	3.86	3.98	3.16	3.20	4.05	3.72
Magnesium	2.37	2.27	2.17	2.47	2.22	2.10	2.04	2.17	2.11	2.22	2.18	2.36
Potassium	0.40	0.32	0.41	0.57	0.55	0.60	0.64	0.50	0.38	0.36	0.44	0.56

Sodium	0.33	0.26	0.32	0.03	0.02	0.11	0.06	0.10	0.13	0.32	0.12	0.06
Calcium	0.21	0.19	0.20	1.91	1.08	0.20	0.22	0.18	0.99	0.20	0.18	0.26

Locations: A- Akwukwu-Igbo, B- Ubulu-Ukwu, C- Emu-Uno, D- Okpai,
E- Aradhe, F- Oleh, G- Otor- Owhe H- Ubeji I- Agbarho, J- Oghara,
K- Udu, L- Ewvreni

Monthly Soil Properties Data under Forested Plots In February

Soil Properties	A	B	C	D	E	F	G	H	I	J	K	L
Sand %	92.0	92.7	90.0	89.8	90.4	90.1	89.9	83.4	90.5	91.2	89.6	90.2
Silt %	9.1	8.5	3.7	3.4	3.5	3.3	3.6	2.6	2.7	2.6	3.2	3.4
Clay %	4.4	3.6	4.5	3.8	3.3	8.7	9.6	3.9	4.3	4.1	4.3	4.8
Bulk Density	1.29	1.31	1.37	1.36	1.28	1.24	1.19	1.41	1.44	1.27	1.31	1.29
Total Porosity	54.6	66.30	63.8	67.4	67.4	66.8	66.9	66.8	66.8	56.8	65.30	66.5
Soil pH (in water)	5.14	5.08	5.61	5.65	5.65	5.06	5.02	5.20	5.60	5.20	5.33	5.41
Organic carbon %	4.46	4.5	5.83	5.12	5.33	4.13	5.18	3.12	4.6	4.9	5.2	5.16
Total Nitrogen %	0.51	0.50	0.32	0.41	0.35	0.60	0.58	0.26	0.19	0.42	0.56	0.48
Available Phosphorous	11.41	11.29	9.89	9.89	9.88	8.88	8.86	7.68	7.78	8.22	8.64	9.20
CEC	4.44	4.12	4,22	3.44	4.92	3.79	3.84	3.17	3.20	3.43	4.10	3.82
Magnesium	2.23	2.23	2.20	2.27	2.33	2.16	2.08	2.14	2.25	2.31	2.19	2.26
Potassium	0.41	0.36	0.51	0.36	0.51	0.58	0.67	0.35	0.31	0.38	0.42	0.51
Sodium	0.32	0.32	0.39	0.04	0.03	0.07	0.06	0.13	0.12	0.29	0.31	0.14
Calcium	0.18	0.22	1.07	1.10	1.06	0.18	0.17	0.98	1.03	0.16	0.20	0.17

Source of Data: Field survey, 2010

Locations: A- Akwukwu-Igbo, B- Ubulu-Ukwu, C- Emu-Uno, D- Okpai,
E- Aradhe, F- Oleh, G- Otor- Owhe H- Ubeji I- Agbarho, J- Oghara,

K- Udu, L- Ewvreni

Monthly Soil Properties Data under Forested Plots In March

Soil Properties	A	B	C	D	E	F	G	H	I	J	K	L
Sand %	91.6	92.8	91.3	89.9	90.4	90.2	89.9	86.9	89.9	89.9	90.3	91.2
Silt %	9.2	8.6	4.3	3.6	3.6	3.2	3.5	2.6	2.7	3.4	3.9	3.6
Clay %	4.5	3.9	4.3	3.7	3.6	8.9	9.7	6.90	4.3	4.3	3.8	4.1
Bulk Density	1.33	1.34	1.35	1.33	1.29	1.27	1.18	1.31	1.43	1.31	1.26	1.34
Total Porosity	65.80	66.1	64.9	67.23	67.37	66.13	66.13	66.14	66.81	66.9	65.13	66.15
Soil pH (in water)	5.12	5.09	5.38	5.66	5.64	5.04	5.03	5.14	5.50	5.40	5.39	5.26
Organic carbon %	5.44	2.09	5.02	4.77	5.24	5.58	5.06	4.35	3.22	5.02	4.88	4.28
Total Nitrogen %	0.73	0.49	0.35	0.40	0.39	0.61	0.58	0.46	0.20	0.43	0.37	0.52
Available Phosphorous	11.22	11.21	1.07	9.89	9.87	8.82	8.89	8.93	7.75	6.24	6.8	8.2
CEC	4.47	4.21	4.13	3.6	4.92	3.86	3.85	3.58	3.18	3.46	3.8	3.62
Magnesium	2.30	2.25	2.19	2.37	2.28	2.13	2.06	2.16	2.18	2.24	2.31	2.14
Potassium	0.41	0.34	0.46	0.46	0.53	0.59	0.65	0.42	0.33	0.41	0.52	0.38
Sodium	0.33	0.29	0.36	0.04	0.03	0.09	0.06	0.12	0.13	0.28	0.10	0.09
Calcium	0.20	0.21	0.13	1.51	1.07	0.19	0.19	0.58	1.01	0.20	0.18	0.21

Source of Data: Field survey, 2010

Locations: A- Akwukwu-Igbo, B- Ubulu-Ukwu, C- Emu-Uno, D- Okpai, E- Aradhe, F- Oleh, G- Otor- Owhe H- Ubeji I- Agbarho, J- Oghara, K- Udu, L- Ewvreni

Monthly Soil Properties Data under Forested Plots In April

Soil Properties	A	B	C	D	E	F	G	H	I	J	K	L
Sand %	90.6	93.7	92.8	88.9	91.4	90.6	89.6	91.2	88.9	89.2	90.6	91.4
Silt %	9.6	8.2	4.4	4.3	3.6	3.4	3.4	2.7	2.4	3.8	3.6	3.6
Clay %	4.7	3.9	4.1	3.4	3.9	9.1	9.7	9.5	4.7	4.8	3.9	4.2
Bulk Density	1.4	1.4	1.33	1.30	1.27	1.32	1.17	1.20	1.40	1.10	1.13	1.21
Total Porosity	64.17	66.70	66.8	67.1	67.1	66.4	66.1	66.4	66.10	66.4	67.2	64.15
Soil pH (in water)	5.07	5.12	5.14	5.67	5.62	5.01	5.03	5.0	5.48	5.30	5.42	5.26
Organic carbon %	6.19	3.92	4.20	4.42	5.14	5.03	4.93	5.58	1.84	4.28	3.61	4.36
Total Nitrogen %	0.90	0.52	0.37	0.39	0.43	0.62	0.61	0.64	0.21	0.42	0.51	0.63
Available Phosphorous	11.01	11.05	11.54	9.88	9.86	8.76	8.92	8.80	7.81	8.66	8.43	8.99
CEC	4.31	4.5	4.04	3.81	4.91	3.93	3.92	3.96	3.14	3.32	3,91	3.96
Magnesium	2.35	2.20	2.26	2.47	2.22	2.10	2.04	2.17	2.11	2.30	2.24	2.13
Potassium	0.38	0.34	0.41	0.57	0.55	0.60	0.64	0.50	0.38	0.36	0.31	0.46
Sodium	0.36	0.23	0.30	0.05	0.02	0.11	0.06	0.10	0.13	0.38	0.28	0.14
Calcium	0.19	0.20	0.21	0.90	1.09	0.19	0.23	0.16	0.98	0.22	0.20	0.18

Locations: A- Akwukwu-Igbo, B- Ubulu-Ukwu, C- Emu-Uno, D- Okpai,
E- Aradhe, F- Oleh, G- Otor- Owhe H- Ubeji I- Agbarho, J- Oghara,
K- Udu, L- Ewvreni

Monthly Soil Properties Data under Forested Plots In May

Soil Properties	A	B	C	D	E	F	G	H	I	J	K	L
Sand %	92.0	93.7	90.2	88.6	91.3	91.1	88.5	83.9	90.5	86.9	88.6	91.2
Silt %	9.4	8.1	3.6	3.5	3.5	3.3	3.6	2.6	2.7	2.6	3.2	3.6
Clay %	4.7	3.3	4.1	3.5	4.0	8.6	9.7	3.9	4.3	4.2	4.7	3.8
Bulk Density	1.3	1.4	1.3	1.4	1.3	1.24	1.17	1.43	1.44	1.4	1.10	1.9
Total Porosity	54.1	66.35	62.7	68.5	67.4	66.5	66.8	66.12	66.8	66.30	67.5	66.2
Soil pH (in water)	5.10	5.12	5.59	5.67	5.65	5.06	5.03	5.20	5.61	5.14	5.10	5.21
Organic carbon %	4.41	5.0	5.73	5.22	5.33	4.13	5.15	5.15	4.6	4.9	5.0	5.09
Total Nitrogen %	0.55	0.45	0.30	0.43	0.35	0.60	0.65	0.28	0.19	0.46	0.37	0.28
Available Phosphorous	11.39	11.31	9.85	9.93	9.88	8.86	8.85	7.71	7.78	8.32	8.38	9.53
CEC	4.40	4.14	4.24	3.44	4.92	3.79	3.84	3.17	3.20	4.16	3.54	3.67
Magnesium	2.19	2.26	2.21	2.27	2.33	2.16	2.08	2.14	2.25	2.19	2.28	2.36
Potassium	0.39	0.38	0.49	0.38	0.51	0.58	0.67	0.35	0.31	0.32	0.41	0.34
Sodium	0.29	0.33	0.35	0.08	0.01	0.09	0.06	0.13	0.12	0.22	0.33	0.16
Calcium	0.16	0.24	1.04	1.13	1.02	0.20	0.16	0.99	1.03	1.10	1.08	1.02

Source of Data: Field survey, 2010

Locations: A- Akwukwu-Igbo, B- Ubulu-Ukwu, C- Emu-Uno, D- Okpai, E- Aradhe, F- Oleh, G- Otor- Owhe H- Ubeji I- Agbarho, J- Oghara, K- Udu, L- Ewvreni

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Monthly Soil Properties Data under Forested Plots In June

Soil Properties	A	B	C	D	E	F	G	H	I	J	K	L
Sand %	90.4	92.3	91.8	90.9	90.7	90.7	89.9	87.8	88.7	90.2	91.4	89.6
Silt %	9.2	8.4	4.5	3.7	3.5	3.2	3.5	2.6	2.7	2.6	3.6	3.5
Clay %	4.6	3.8	4.5	3.7	3.9	8.7	9.7	6.8	4.4	4.7	3.8	4.4
Bulk Density	1.35	1.31	1.36	1.33	1.29	1.27	1.18	1.34	4.40	1.36	1.28	1.19
Total Porosity	66.82	66.4	65.14	66.24	67.37	66.13	66.13	66.25	66.70	66.72	65.8	66.16
Soil pH (in water)	5.12	5.09	5.38	5.66	5.64	5.04	5.06	5.12	5.99	5.13	5.13	5.32
Organic carbon %	5.42	2.11	5.09	4.70	5.24	5.58	5.06	4.30	3.27	3.32	4.22	3.27
Total Nitrogen %	0.71	0.48	0.38	0.40	0.39	0.61	0.58	0.46	0.20	0.51	0.48	0.56
Available Phosphorous	11.27	11.14	1.05	9.88	9.87	8.85	8.89	8.93	7.75	8.64	8.52	7.88
CEC	4.39	4.29	4.13	3.6	4.92	3.86	3.85	3.50	3.26	3.39	4.12	4.42
Magnesium	2.30	2.25	2.19	2.37	2.28	2.13	2.06	2.14	2.20	2.24	2.18	2.36
Potassium	0.40	0.31	0.51	0.46	0.53	0.59	0.65	0.44	0.31	0.41	0.38	0.46
Sodium	0.36	0.26	0.32	0.08	0.03	0.09	0.06	0.12	0.13	0.34	0.10	0.16
Calcium	0.18	0.22	0.15	0.49	1.07	0.19	0.21	0.56	1.01	0.19	0.20	0.52

Source of Data: Field survey, 2010

Locations: A- Akwukwu-Igbo, B- Ubulu-Ukwu, C- Emu-Uno, D- Okpai, E- Aradhe, F- Oleh, G- Otor- Owhe H- Ubeji I- Agbarho, J- Oghara, K- Udu, L- Ewvreni

Monthly Soil Properties Data under Forested Plots In July

Soil Properties	A	B	C	D	E	F	G	H	I	J	K	L
Sand %	91.2	92.4	92.7	89.9	90.7	90.7	89.9	90.6	89.6	88.4	88.6	90.2
Silt %	9.1	8.7	4.9	3.7	3.7	3.4	3.4	2.7	2.4	2.8	3.6	3.4
Clay %	4.3	4.3	4.1	3.5	3.8	9.3	9.9	9.7	4.0	3.9	4.0	4.3
Bulk Density	1.36	1.36	1.33	1.30	1.29	1.30	1.17	1.21	1.41	1.38	1.32	1.29
Total Porosity	65.4	65.83	66.8	67.1	67.0	66.5	66.1	66.03	66.10	66.5	66.2	66.9
Soil pH (in water)	5.08	5.11	5.14	5.67	5.52	5.11	5.03	5.04	5.44	5.57	5.16	5.11
Organic carbon %	6.24	3.87	4.20	4.42	5.14	5.03	4.93	5.60	1.82	2.86	3.20	3.19
Total Nitrogen %	0.91	0.49	0.39	0.39	0.43	0.62	0.59	0.67	0.20	0.60	0.41	0.52
Available Phosphorous	11.06	11.1	11.56	9.81	9.90	8.76	8.92	8.85	7.76	9.60	8.88	8.22
CEC	4.50	4.1	4.06	3.81	4.91	3.93	3.86	3.0	3.14	4.0	3.82	3.91
Magnesium	2.37	2.27	2.17	2.49	2.20	2.10	2.04	2.17	2.11	2.37	2.42	2.12
Potassium	0.41	0.31	0.44	0.55	0.54	0.60	0.64	0.52	0.36	0.31	0.44	0.54
Sodium	0.26	0.33	0.32	0.03	0.02	0.11	0.06	0.09	0.14	0.10	0.13	0.08
Calcium	0.19	0.21	0.20	1.90	1.09	0.20	0.22	0.19	0.98	0.19	0.28	0.20

Source of Data: Field survey, 2010

Locations: A- Akwukwu-Igbo, B- Ubulu-Ukwu, C- Emu-Uno, D- Okpai, E- Aradhe, F- Oleh, G- Otor- Owhe H- Ubeji I- Agbarho, J- Oghara, K- Udu, L- Ewvreni

Monthly Soil Properties Data under Forested Plots In August

Soil Properties	A	B	C	D	E	F	G	H	I	J	K	L
Sand %	92.4	92.5	90.4	8.4	90.4	90.1	89.9	83.5	90.4	91.4	90.6	88.9
Silt %	9.0	8.4	3.9	3.4	3.4	3.2	3.7	2.6	2.8	2.8	3.4	3.6
Clay %	4.6	3.4	4.5	3.9	3.4	8.6	9.6	3.8	4.4	3.8	4.1	4.4
Bulk Density	1.31	1.28	1.38	1.36	1.26	1.26	1.19	1.43	1.42	1.28	1.36	1.38
Total Porosity	66.31	54.5	63.8	67.4	66.2	66.10	66.9	66.2	66.14	66.8	66.4	56.10
Soil pH (in water)	5.12	5.10	5.61	5.02	5.65	5.06	5.65	5.16	5.64	5.14	5.08	5.46
Organic carbon %	4.48	4.3	5.83	4.13	5.33	5.12	5.18	3.12	4.6	3.31	4.6	4.15
Total Nitrogen %	0.54	0.47	0.32	0.60	0.35	0.41	0.58	0.26	0.19	0.44	0.36	0.29
Available Phosphorous	11.28	11.42	9.89	9.89	9.80	8.96	7.78	7.68	8.86	7.88	8.64	8.72
CEC	4.16	4.40	4.90	3.44	4.22	3.79	3.86	3.10	3.27	3.41	3.90	3.52
Magnesium	2.20	2.21	2.22	2.23	2.33	2.16	2.08	2.16	2.23	2.28	2.32	2.19
Potassium	0.36	0.36	0.51	0.41	0.51	0.58	0.69	0.34	0.30	0.36	0.42	0.51
Sodium	0.39	0.32	0.32	0.04	0.04	0.06	0.06	0.13	0.12	0.33	0.28	0.14
Calcium	0.17	0.23	1.07	1.09	1.07	0.98	0.17	0.18	1.03	0.16	0.26	0.22

Source of Data: Field survey, 2010

Locations: A- Akwukwu-Igbo, B- Ubulu-Ukwu, C- Emu-Uno, D- Okpai,
E- Aradhe, F- Oleh, G- Otor- Owhe H- Ubeji I- Agbarho, J- Oghara,
K- Udu, L- Ewvreni

Monthly Soil Properties Data under Forested Plots In September

Soil Properties	A	B	C	D	E	F	G	H	I	J	K	L
Sand %	90.9	91.6	91.4	89.4	90.6	90.2	89.4	87.1	88.9	88.6	90.2	89.2
Silt %	9.4	8.7	4.2	3.7	3.5	3.3	3.4	2.5	2.8	3.8	3.4	3.8
Clay %	4.3	4.0	4.2	3.8	4.0	8.4	9.8	6.91	4.7	4.0	4.8	4.3
Bulk Density	1.37	1.34	1.35	1.33	1.29	1.18	1.27	1.31	1.43	1.32	1.36	1.28
Total Porosity	65.88	65.1	65.9	67.23	67.37	66.13	66.13	66.10	66.85	66.85	65.8	67.12
Soil pH (in water)	5.14	5.04	5.42	5.66	5.64	5.04	5.03	5.10	5.54	5.12	5.31	5.26
Organic carbon %	5.38	2.06	5.05	4.77	5.24	4.35	5.06	5.58	3.22	4.06	3.82	4.33
Total Nitrogen %	0.69	0.47	0.37	0.40	0.39	0.61	0.20	0.46	0.58	0.56	0.48	0.38
Available Phosphorous	11.24	11.19	1.09	9.87	9.89	8.82	8.89	3.98	7.70	7.61	8.14	8.24
CEC	4.39	4.21	4.13	3.6	4.92	3.86	3.89	3.55	3.19	4.18	3.82	3.76
Magnesium	2.31	2.25	2.19	2.37	2.28	2.13	2.10	2.20	2.10	2.14	2.22	2.31
Potassium	0.40	0.34	0.42	0.50	0.53	0.59	0.63	0.44	0.33	0.36	0.48	0.43
Sodium	0.32	0.27	0.38	0.03	0.04	0.07	0.08	0.12	0.13	0.27	0.18	0.08
Calcium	0.21	0.19	0.15	0.48	1.10	0.18	0.20	1.50	1.09	0.20	0.16	0.10

Source of Data: Field survey, 2010

Locations: A- Akwukwu-Igbo, B- Ubulu-Ukwu, C- Emu-Uno, D- Okpai,
E- Aradhe, F- Oleh, G- Otor- Owhe H- Ubeji I- Agbarho, J- Oghara,
K- Udu, L- Ewvreni

Monthly Soil Properties Data under Forested Plots In October

Soil Properties	A	B	C	D	E	F	G	H	I	J	K	L
Sand %	90.4	89.8	95.3	89.1	90.5	89.9	85.6	84.2	89.3	85.8	90.2	94.1
Silt %	7.1	4.3	6.8	6.4	4.4	3.9	4.5	6.4	11.8	4.6	5.2	5.8
Clay %	2.8	2.6	4.5	2.6	2.6	6.0	4.5	3.7	4.9	4.5	3.8	4.2
Bulk Density	1.41	1,43	1.43	1.29	1.40	1.30	0.73	1.04	1.19	1.31	1.28	1.42
Total Porosity	63.0	66.24	62.83	63.13	66.44	63.05	60.74	59.49	60.4	64.2	60.5	62.8
Soil pH (in water)	5.30	4.92	4.73	4.64	5.00	4.68	5.35	5.26	4.7	5.02	4.84	4.50
Organic carbon %	4.17	4.06	1.09	3.88	4.38	1.14	4.45	3.80	0.22	3.88	4.02	3.96
Total Nitrogen %	0.54	0.35	0.30	0.30	0.35	0.21	0.51	0.70	0.20	0.36	0.28	0.41
Available Phosphorous	6.42	6.69	4.62	5.69	7.57	7.39	2.98	4.66	3.13	4.58	5.72	6.53
CEC	0.96	4.04	3.60	2.76	3.19	2.11	2.11	2.00	0.33	2.81	3.16	3.64
Magnesium	3.41	3.24	2.75	3.71	2.02	3.40	1.07	0.92	2.91	3.20	2.78	3.06
Potassium	0.11	0.31	0.08	0.09	0.12	0.08	0.42	0.23	0.30	0.12	0.21	0.14
Sodium	0.24	0.03	0.23	0.26	0.30	0.36	0.47	0.03	0.31	0.20	0.18	0.34
Calcium	0.15	0.20	0.48	0.27	0.13	0.14	0.08	0.05	0.07	0.14	0.08	0.10

Source of Data: Field survey, 2010

Locations: A- Akwukwu-Igbo, B- Ubulu-Ukwu, C- Emu-Uno, D- Okpai, E- Aradhe, F- Oleh, G- Otor- Owhe H- Ubeji I- Agbarho, J- Oghara, K- Udu, L- Ewvreni

Monthly Soil Properties Data under Forested Plots In November

Soil Properties	A	B	C	D	E	F	G	H	I	J	K	L

Sand %	90.7	92.0	92.2	89.6	90.4	90.1	89.9	83.6	90.3	88.4	89.2	90.0
Silt %	9.4	8.1	3.5	3.6	3.5	3.3	3.6	2.8	2.5	2.8	3.2	3.2
Clay %	4.6	3.4	4.6	3.7	3.3	8.8	9.4	3.7	4.5	4.1	3.4	3.6
Bulk Density	1.29	1.31	1.37	1.36	1.28	1.24	1.19	1.45	1.41	1.30	1.34	1.28
Total Porosity	66.30	67.4	63.8	67.4	54.6	66.8	66.9	66.4	66.12	66.40	66.6	55.8
Soil pH (in water)	5.16	5.04	5.59	5.67	5.65	5.06	5.02	5.15	5.65	5.42	5.23	5.18
Organic carbon %	4.49	4.2	5.79	5.16	5.33	4.13	5.18	3.10	4.8	4.2	4.14	4.19
Total Nitrogen %	0.55	0.45	0.32	0.41	0.35	0.60	0.61	0.24	0.18	0.45	0.36	0.24
Available Phosphorous	11.39	11.31	9.90	9.88	9.80	8.90	7.78	7.68	8.86	7.82	8.63	8.92
CEC	4.46	4.10	4.20	3.46	4.92	3.79	3.80	3.22	3.19	3.52	3.46	3.28
Magnesium	2.21	2.25	2.25	2.22	2.33	2.16	2.10	2.12	2.26	2.24	2.14	2.32
Potassium	0.45	0.32	0.51	0.36	0.51	0.58	0.67	0.33	0.33	0.42	0.31	0.52
Sodium	0.36	0.31	0.35	0.05	0.03	0.07	0.05	0.12	0.14	0.35	0.29	0.13
Calcium	0.20	0.20	1.07	1.10	1.08	0.17	0.16	0.92	1.09	0.19	0.22	1.04

Source of Data: Field survey, 2010

Locations: A- Akwukwu-Igbo, B- Ubulu-Ukwu, C- Emu-Uno, D- Okpai, E- Aradhe, F- Oleh, G- Otor- Owhe H- Ubeji I- Agbarho, J- Oghara, K- Udu, L- Ewvreni

Monthly Soil Properties Data under Forested Plots In December

Soil Properties	A	B	C	D	E	F	G	H	I	J	K	L
Sand %	91.1	91.6	92.8	89.9	90.6	90.5	89.9	86.5	90.1	90.2	89.6	91.8

Silt %	9.5	8.1	4.5	3.2	3.8	3.3	3.4	2.7	2.6	3.8	3.4	4.2
Clay %	4.7	3.7	4.3	3.7	3.7	8.6	9.8	6.4	4.8	4.8	4.6	3.4
Bulk Density	1.35	1.31	1.36	1.27	1.29	1.33	1.19	1.29	1.46	1.33	1.26	1.31
Total Porosity	67.23	66.13	64.9	65.80	67.37	66.1	66.13	66.14	66.81	67.23	65.9	66.88
Soil pH (in water)	5.14	5.07	5.38	5.66	5.64	5.04	5.03	5.10	5.54	5.16	5.44	5.08
Organic carbon %	5.47	2.07	5.02	5.06	5.24	5.58	4.77	4.30	3.27	3.35	4.26	4.32
Total Nitrogen %	0.74	0.41	0.42	0.40	0.39	0.61	0.58	0.40	0.26	0.63	0.44	0.38
Available Phosphorous	11.26	11.17	1.06	9.90	9.87	8.85	8.89	8.97	7.68	8.76	8.82	9.26
CEC	4.44	4.24	4.13	3.6	4.92	3.86	3.18	3.58	3.85	4.34	3.9	3.88
Magnesium	2.35	2.20	2.19	2.16	2.28	2.18	2.06	2.37	2.13	2.27	2.18	2.33
Potassium	0.46	0.40	0.40	0.41	0.53	0.33	0.65	0.42	0.59	0.41	0.09	0.18
Sodium	0.36	0.29	0.33	0.04	0.03	0.08	0.07	0.11	0.14	0.18	0.24	0.09
Calcium	0.19	0.22	0.15	1.49	1.06	0.20	0.21	0.56	1.01	0.19	0.46	1.04

Source of Data: Field survey, 2010

Locations: A- Akwukwu-Igbo, B- Ubulu-Ukwu, C- Emu-Uno, D- Okpai, E- Aradhe, F- Oleh, G- Otor- Owhe H- Ubeji I- Agbarho, J- Oghara, K- Udu, L- Ewvreni